DEEP-SEA SHRIMP FISHERY OFF KERALA COAST WITH EMPHASIS ON BIOLOGY AND POPULATION CHARACTERISTICS OF *PLESIONIKA QUASIGRANDIS* CHACE, 1985

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Central Marine Fisheries Research Institute

November 2014

Declaration

I, Rajool Shanis C.P., do hereby declare that the thesis entitled **Deep-sea shrimp fishery off Kerala coast with emphasis on biology and population characteristics of *Plesionika quasigrandis* Chace, 1985** is an authentic record of research work carried out by me under the supervision and guidance of Dr. N.G.K. Pillai, ICAR Emeritus Scientist, Central Marine Fisheries Research Institute (CMFRI), Kochi, in partial fulfillment of the requirement for the award of Ph.D. degree of the Cochin University of Science and Technology in the Faculty of Marine Sciences and no part of this work has previously formed the award of any degree, associateship, fellowship or any other title or recognition.

Kochi – 682 018 **Rajool Shanis C.P.**

November 2014

भारतीय कृषि अनुसंधान परिषद
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केन्द्रीय समुद्री मात्स्यिकी अनुसंधान संस्थान
Central Marine Fisheries Research Institute

Certificate

This is to certify that the thesis entitled **Deep-sea shrimp fishery off Kerala coast with emphasis on biology and population characteristics of *Plesionika quasigrandis* Chace, 1985** is an authentic record of research work carried out by Mr. RAJOOL SHANIS C.P., Full-time Research Scholar of this Institute and registered student for Ph.D. degree in Faculty of Marine Sciences, Cochin University of Science and Technology (Reg. No. 3484) under my guidance and supervision and no part of this work has previously presented for the award of any degree, diploma, associateship, fellowship or other similar titles or recognition.

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General Introduction

1.1 Introduction

Fish and fishery products are one of the most widely traded food items of world and play a pivotal role in the global food and nutritional security. Fisheries constitute an important sector in many maritime nations, not only as a major food source but also as a generator of foreign exchange earnings and employment. Fish contributes 17% of the global population's intake of animal protein and provides essential minerals, vitamins and omega-3 fatty acids (FAO, 2014). The fisheries sector is a source of employment for more than 200 million people of worldwide (FAO, 2011). In comparison to the other sectors of the world food production, the fisheries and aquaculture sectors are poorly planned and inadequately funded (USAID, 2011).

The capture fisheries sector is one of the fastest growing food sectors in India, in addition to aquaculture. The country also has a significant role in global fisheries as the second largest producer of fish in the world. In India, marine fishery sector is largely constituted by capture fisheries. The present annual production is about 3.78 million tonnes (mt), forming 85.7% of the potential yield of 4.41 mt, the split up being, 2.13 mt of pelagic, 2.07 mt of demersal and 0.22 mt of oceanic resources (DAHDF, 2013; CMFRI, 2014).

Over the past few years the marine fishery sector of Kerala has been one of the major contributors to fish production in India. Kerala is the third largest contributor to the national marine fish production and generates around 6.7 lakh tonnes (t) of fish annually with sizeable contribution by pelagic fishes (73.2%) followed by demersal fishes (13.9 %), crustaceans (6.1%) and molluscan resources (6.6%) (CMFRI, 2014). Kerala economy has shown a consistent growth of 4.5 per cent, triggering an increased purchasing power of consumers, thus leading to high fish consumption. The per capita fish consumption in Kerala was found to be 27 kg /year which is thrice that of the national average (Shyam *et al*., 2013a).

Beyond the fact that the shrimps are small in size, they collectively represent the biggest and the most valuable seafood commodity traded worldwide. Over the last two decades the worldwide production of shrimp has increased exponentially and accounts for 16% of global seafood exports (FAO, 2014). Shrimps occupy a prominent position in the economy of India on account of their high export value. During the year 2013–14 shrimp exports alone generated a value of US$ 3210.94 million from an export quantum of 3, 01,435 tonnes (MPEDA, 2014). In addition, the domestic shrimp consumption is on the rise with increased consumer willingness to pay for shrimp across the different regions of India (Shyam, 2013b). The present landings of marine shrimp in the country is estimated to be 4.1 lakh tonnes which represents 61% of the total crustacean catch and 8.5% of the total marine fish landings (CMFRI, 2014). Landings of marine shrimps in India showed significant fluctuations between 1990 and 2013 and reached a maximum catch in 2011 (4.6 lakh tonnes) and minimum in 1993 (2.46 lakh tonnes) (Fig.1.1). Average annual shrimp catch in India during 1990–2013 was 3.39 lakh tonnes, of which 59.5% was contributed by penaeid shrimps and 40.5% by non-penaeid shrimp (CMFRI, 2008-2014; Radhakrishnan 2011). According to Rao (2013) about 85% of the non-penaeid shrimp catch of the country was landed along the northwest coast.

The decline of resources in shallow coastal waters, together with increasing demand and new technological developments resulted in expansion of fisheries to offshore areas and in to deeper waters (Pauly *et al.*, 2005; Morato *et al.*, 2006). Deep-sea species are characterised by slow growth, long lifespan, late maturity and low fecundity and are adapted to live in an ecosystem of low energy turnover in which major environmental changes occur infrequently (ICES, 2001).

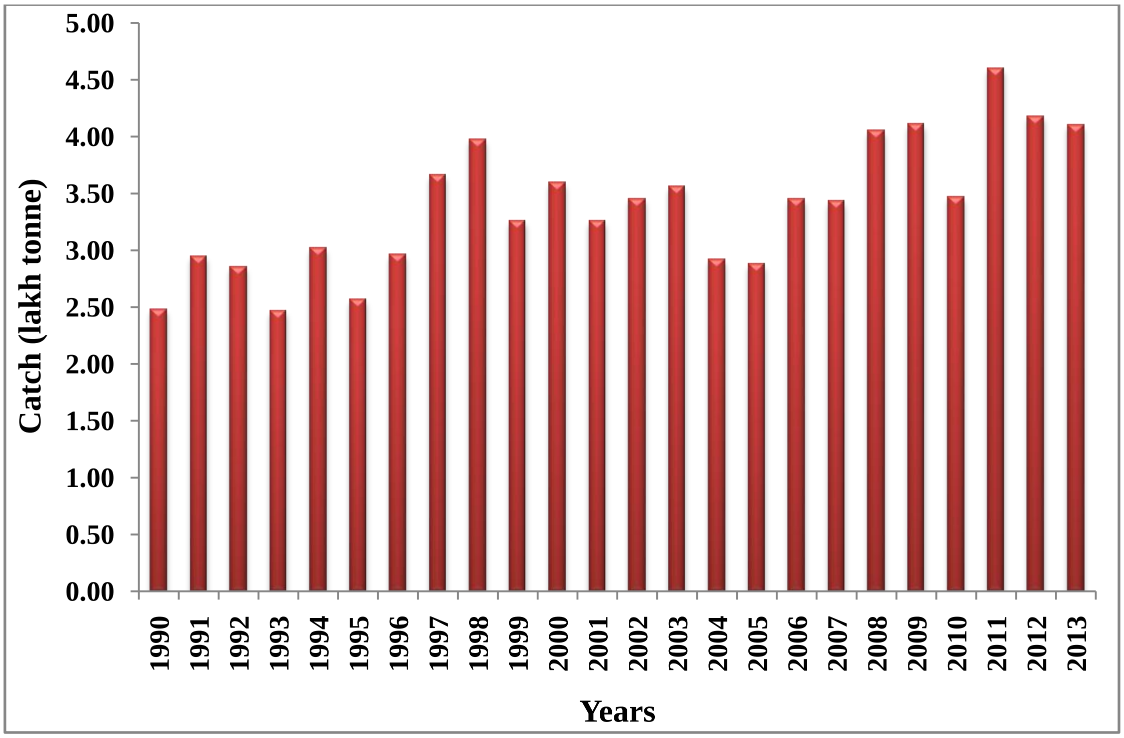


Figure 1.1. Marine shrimp landing of India during 1990-2013 (Source: CMFRI)

The knowledge and exploitation of deep-sea fishing grounds resulted in the emergence of new commercially important species in the fishery, especially shrimps which acquired one of the highest export values. Globally several deep-sea shrimps are commercially exploited at present. Species belonging to family Pandalidae and Aristeidae play an important role in the world's deep-sea shrimp fisheries (Gillett, 2008). Besides the economic importance, most of the deep-sea shrimps occupy significant ecological role in the marine ecosystem and forms key element in the marine food web accountable for the transfer of energy to benthic habitat (Maynou and Cartes, 1998; Cartes *et al*., 2002).

In India, development of deep-sea fisheries sector has shown a slow pace probably due to lack of awareness, infrastructure, expertise and government support. The current level of commercial exploitation of deep-sea resources is mainly focused on deep-sea shrimps and sharks (Akhilesh *et al.*, 2011; Rajool Shanis *et al.*, 2012). The current trend shows that the consumption of fish is on a rise and there has been an unceasing increase of issues pertaining to food security in terms of spiraling of the fish prices as well as non-availability of fish. With the decrease in catch per unit effort of fishery resources, there is a critical requisite to identify new fishery resources to sustain the food fish security of the country. Expanding fisheries to the unexploited deep-sea area has been considered as a substitute to the effort reduction on the coastal area. Considering this, some initiatives were carried out by the government of India to identify new potential fishing grounds in the deep-sea area of Indian EEZ (Silas, 1969; Mohamed and Suseelan, 1973; James and Pillai, 1990; Suseelan *et al.*, 1989; Ninan *et al*., 1992; Jayaprakash *et al.*, 2006; Sajeevan *et al.*, 2009; Hashim, 2012).

One of the major constraints for the development and implementation of management measures for the sustainable harvest of deep-sea fishery resources is the lack of information on biological aspects of the exploited species (Polidoro *et al.*, 2008). Despite the fact that deep-sea shrimps are one of the important fisheries in Kerala, there is a lack of necessary information on the trends in fishery, biology and population parameters of most of the deep-sea shrimp species in this region. Therefore, the detailed studies on the taxonomy, fishery, biology, and stock assessment of one of the dominant deep-sea shrimps, *Plesionika quasigrandis* of Kerala coast would be helpful to the rational exploitation and the implementation of management strategies.

1.2 Review of literature

Taxonomy and diversity

The taxonomic studies on deep-sea crustaceans from Indian waters dates back to early the 20th century were mainly based on samples collected during the surveys of the Royal Indian Marine Survey ship (RIMS) *Investigator* (Wood-Mason, 1873; Wood-Mason and Alcock, 1891, 1893; Alcock and Anderson, 1894, 1899; Alcock, 1901; Lloyd, 1907; Kemp, 1925). Several new deep-sea crustaceans were described from Arabian Sea, Bay of Bengal and Andaman Sea based on these collections. A detailed description and compilation of deep-sea crustaceans found in the seas around India was provided by Alcock (1901) based on collection of the RIMS *Investigator* during the period 1885-1900. This catalogue comprised of 117 species of deep-sea crustaceans of which 85 were deep-sea shrimps. The expeditions in the Indian Ocean region also described and reported variety of new deep-sea crustaceans (Ramadan, 1938; Calman, 1939; Tirmizi, 1960; Tirmizi and Bashir, 1973).

After the studies based on collections of RIMS '*Investigator*', the deep-sea crustacean fauna of Indian waters was little studied and documented. The information on distribution and abundance of deep-sea species from Indian waters was reported by the exploratory surveys conducted by Central Marine Fisheries Research Institute, Indo-Norwegian Project, Fishery Survey of India, and Department of Ocean Development/Centre for Marine Living Resources and Ecology. However, the detailed taxonomic studies of deep-sea crustaceans were restricted to only few species. The exploratory research vessels *Conch, Kalava, Varuna, Klaus Sunnana, Velameen* and *Tuna* conducted surveys along the west coast of India. John and Kurian (1959) and

Kurian (1964) provided the details of deep-sea shrimps and lobsters of Kerala coast. George (1966) reported the occurrence of deep-sea penaeid shrimps from the off shore waters of the south-west coast of India. Silas (1969) provided the details of catch and abundance of species collected during the exploratory surveys of R. V. *Varuna*. Mohamed and Suseelan (1973) reported the abundance and distribution of deep-sea shrimp resources off the south-west coast of India. Thomas (1979) provided detailed information on deep-sea decapod crustaceans from the Gulf of Mannar. Suseelan (1974) studied the diversity of deep-sea pandalid shrimps off the south-west coast of India. Oommen (1980) provided information on the exploratory fishery survey conducted off Quilon Bank and Gulf of Mannar.

Since 1984, the Fisheries and Oceanographic Research Vessel (FORV) *Sagar Sampada* has been conducting exploratory fishery resource surveys in the Indian EEZ. Suseelan *et al.* (1989) gave a detailed account on the deep-sea crustaceans off southwest coast of India based on the collection from FORV *Sagar Sampada.* James and Pillai (1990) provided information on the fishes and crustaceans in deep-sea areas of the Indian waters based on the surveys conducted during the period 1985 to 1988. Taxonomic account of deep-sea pandalid shrimps *Plesionika williamsi*, *P. ensis* and *Heterocarpus sibogae* from Indian waters was provided by Suseelan and Mohamed (1968) and Suseelan (1990).

Suseelan (1989) provided taxonomic account of the aristeid shrimp *Aristeus alcocki* collected from the west coast of India. Ninan *et al*. (1992) provided the data on the abundance and diversity of deep-sea resources off Wedge Bank and Gulf of Mannar. Bhargava *et al.* (1994) reported the distribution and abundance of deep-sea shrimps along the south- west coast of India as revealed by chartered foreign fishing vessels operations during the period 1990-1994. Jayaprakash *et al.* (2006) has given the details of distribution pattern and abundance of deep-sea fishes and decapod crustaceans from the south west coast of India as revealed by FORV *Sagar Sampada*. Suseelan and George (1990) and Ganga *et al.* (2012) reported the occurrence and provided taxonomic account of deep-sea aristaeid shrimp, *Aristaeopsis edwardsiana* off Trivandrum.

Fishery and biology

Information on fishery of commercially important deep-sea shrimp species are available from a number of contributions around the world. Some of the important studies in this area are that of Ribeiro (1987) from south coast of Portugal, Darryl and Scott (1998) from Hawaiian archipelago, Sarda (2000) from Mediterranean Sea, Figueiredo *et al.* (2001) from Portuguese waters, Belcari *et al.*(2003) in the Northern Tyrrenian Sea, Ragonese *et al*. (2001) and Stefano *et al.* (2006) in the Strait of Sicily, Perez *et al.* (2003), Pezzuto *et al.* (2006) and Dallagnolo *et al.* (2009) from Brazil waters, Sarda *et al.* (2004) from the western and central Mediterranean Sea, Mytilineou *et al.* (2006) from eastern Ionian Sea, Margot *et al.* (2007) from Gulf of Mexico, Mouffok *et al.* (2008) from Algerian waters and Paramo and Ulrich (2011) from the Colombian Caribbean Sea. Perez *et al*. (2009) discussed history, status and perspectives of the deep-sea fisheries in Brazil. King (1988) reviewed shrimp trap fishery and biology of deep-sea shrimps of Pacific waters. Trap fishery for deep-sea shrimps has been reported in the central eastern Atlantic (Gonzalez *et al.,* 1997; Santana *et al.,* 1997) and from the Mediterranean Sea (Thessalou-Legaki, 1989; Garcia *et al.*, 2000). Most shrimp traps used in the Mediterranean Sea are cylindrical and made from one cm mesh plastic screen. They are baited with horse mackerel, scabbard fish, common mackerel etc. (Vafidis *et al.*, 2005)

The commercial fishery for deep-sea shrimps in India was started during the late 1990's employing conventional shrimp trawlers (Dineshbabu *et al.*, 2001; Rajan *et al.*, 2001; Rajamani and Manickaraja, 2003; Thirumilu and Rajan, 2003; CMFRI, 2004). In Kerala, the landing of deep-sea shrimps peaked during the initial period and then dropped significantly in the following years (Radhika and Kurup, 2005). Even though economic efficiency of fishing operations of different fishing units from Indian coast have been studied by many researchers (Devaraj and Smitha, 1988; Sathiadhas and Panikkar, 1989; Sehara and Karbhari, 1989; Sathiadhas *et al.*,1991,1992,1993; Sehara *et al*., 1998; Sathiadhas and Narayanakumar, 2001; Narayanakumar and Sathiadhas, 2005; Najmudeen and Sathiadhas, 2007; Narayanakumar *et al*., 2009; Femeena and Sathiadhas, 2009; Aswathy *et al.*, 2011; Geetha *et al.*, 2014), there is no literature available on the economic performance of deep-sea shrimp trawlers.

Understanding the reproductive aspects of a species is an important prerequisite for providing scientific advice for its fisheries management to enable optimum exploitation of the concerned species in tune with its reproductive characteristics (Ganga, 2010). Maiorano *et al.* (2002) provided information on life history traits of *Plesionika martia* from the eastern-central Mediterranean Sea. Possenti *et al.* (2007) studied reproductive aspects of females of *P. edwardsii* from northern Tyrrhenian Sea. Company and Sarda (1997) described the reproductive biology of *Plesionika acanthonotus, P. edwardsii, P. gigliolii, P. heterocarpus* and *P. martia* from north western Mediterranean Sea. Colloca (2002) gave an account of reproductive aspects of *P. edwardsii* from central Mediterranean Sea. Detailed studies of reproductive biology and life history pattern of pandalid shrimp *P. izumiae* was described from Japan waters (Omori, 1971; Ahamed and Ohtomi, 2011). Ohtomi (1997) provided information on reproductive pattern of *P. semilaevis* from Kagoshima Bay. Chilari *et al.* (2005) studied the reproductive biology and population structure of *P. martia* from Eastern Ionian Sea. Thessalou-legaki (1989) and ColIoca (2002) gave an account of the life history traits of *P. narval* and *P. edwardsii* from Central Mediterranean Sea. Wilder (1974) studied the reproductive biology and other biological aspects of deep-sea pandalid shrimp such as *Heterocarpus ensifer* and *H. laevigatus* from western Pacific Ocean.

The preliminary studies on the reproductive aspects of *Heterocarpus longirostris* from the northern Marianas Islands was conducted by Moffit (1983). King and Moffitt (1984) provided the information on the sexuality of tropical deep-sea shrimps. The life history pattern and its relationship with depth of deep-sea caridean shrimps were described by King and Butler (1985). Santana *et al*. (1997) studied the life history of *P. edwardsii* from eastern central Atlantic. Company *et al.* (2003) compared the reproductive periods of the decapod crustacean community dwelling in transitional environments, from shallow habitats to deep-sea habitats and correlated these reproductive processes with the spatial-temporal variability of organic fluxes input to these habitats. Lozano *et al.* (2007) provided the information on reproductive pattern of *H. ensifer* from the Gulf of Mexico. Victor *et al.* (2009) provided the detailed information of the reproductive biology of *H. ensifer* from north eastern Atlantic. Silvia and Ingo (2011) described egg production of the pandalid shrimp, *H. vicarious* from Pacific Costa Rica.

Detailed investigations on the reproductive biology of deep-sea shrimps *Heterocarpus gibbosus* and *H. woodmasoni* was conducted by Radhika (2004) from

Southern Arabian Sea. A preliminary account of reproductive aspects like sex ratio, fecundity and egg size of the deep-sea shrimps were reported by Rao and Suseelan (1967), Menon (1972), Mohamed and Suseelan (1973), Suseelan (1974) and Suseelan *et al.,* (1990), Rajan *et al.* (2001) and Thirumilu and Rajan (2003) from Indian waters.

Aquatic organisms devote great portion of their energy for searching food items. Studies on the feeding habits and diet composition help to understand the rate of growth, population concentration, maturation of gonads and other metabolic activities of marine organisms (Kulkarni *et al.,* 1999). Deep-sea shrimps are generally non-migratory macro plankton feeders and they play a significant role in the trophic web (Vafidis *et al.,* 2005). Studies on the feeding habits and diet composition of deep-sea shrimps in Indian waters are limited to few species such as *Penaeopsis jerryi*, *P. philippi*, *P. rectacutus, H. gibbosus* and *H. woodmasoni* (Kurian, 1964, 1965; Suseelan, 1974; Radhika, 2004). Flock and Hopkins (1992) reported the feeding habits of eleven sergestid shrimp species and observed that they mainly feed on crustaceans. Natural feeding habits of *Sergestes similies* was described from the Santa Barbara Basin by Genthe (1969). Cartes (1993) investigated day-night feeding habits and diet composition of six species of deep-sea shrimps *Pasiphaeia multidentala*, *Aristeus antennatus, Acanthephyra eximia, P. martia, P. edwardsii* and *P. acanthonotus* from Catalan Sea. Detailed studies were conducted on the feeding habits of commercially important deep-sea red shrimps such as *A. antennatus* and *A. foliacea* (Cartes and Sarda, 1989; Cartes, 1994; Kapiris *et al.,* 1999; Kapiris, 2004; Chartosia *et al.,* 2005; Cartes *et al.,* 2008; Kapiris and Thessalou-Legaki, 2011) and species belonging to *Plesionika* genus *P. martia, P. gigliolii, P. edwardsii, P. heterocarpus, P. acanthonotus* and *P. narval* (Cartes, 1993; Fanelli and Cartes, 2004; Kitsos *et al.,* 2008). Cartes (1998) described the feeding strategies and partition of food resources in deep-sea decapod crustaceans in relation to depth. Deep-sea decapod species are active predators of benthic invertebrates and exhibit highly diverse diets, but dietary diversity was higher for those inhabiting shallower depths (Mary and Ioannis, 1999).

Deep-sea environment is characterized by ecological stability and by relative scarcity of available food resources (Tyler, 1988). Wenner (1979), Cartes and Abello (1992) and Fanelli and Cartes (2004) have reported high percentage of empty stomach in deep-sea decapod crustaceans. Generally the feeding intensity fluctuates with available prey species rather than with this abiotic factor (Yunrong *et al.*, 2011). According to Kitsos *et al.* (2008) deep-sea pandalid shrimp *P. narval* is an active predator and also an occasional scavenger, utilizing a wide variety of benthic resources. The diet composition, dietary diversity and feeding activity between different size groups of deep-sea aristeid shrimp reveal that species undergoes changes in feeding habits with increasing body size and gonad maturity (Kostas Kapiris, 2012).

Growth parameters and Stock assessment

Basic aim of stock assessment studies is to provide advice on the optimum exploitation and sustainable management of fishery resources. Stock assessment describes the present and past status of a fish stock. Focal studies on growth parameters and stock assessment of coastal shrimps from Indian waters included *Metapenaeus dobsoni* (Ramamurthy *et al.*, 1978; Alagaraja *et al.*, 1986; George *et al.*,1988; Pillai and Thirumilu, 2013), *Parapenaeopsis stylifera* (Ramamurthy,1980; Alagaraja *et al.*, 1986; Suseelan and Rajan, 1989), *M. monoceros* (Lalitha Devi, 1987; Rao, 1994; Nandakumar, 1997), *Exhippolysmata ensirostris* (Deshmukh, 1990), *Acetes indicus* (Deshmukh, 1993), *Solenocera crassicornis* (Chakraborty *et al.*,1997), *Penaeus* spp. (Banerji and Geroge, 1967; Kurup and Rao, 1974; Lalitha Devi, 1986; Rao, 1988; Rao *et al.*,1993), *Penaeus merguiensis* (Bhadra and Biradar, 2000), *Nematopalaemon tenuipes* (Kizhakudan and Deshmukh, 2009), *Solenocera choprai* (Dineshbabu and Manisseri, 2009), *Metapenaeopsis stridulans* (Pillai *et al.*, 2012), *Melicertus latisulcatus* (Sundaramoorthy *et al.*, 2013). Detailed study on the growth parameters and stock assessment of commercial shrimps in shallow waters shows that the average annual yields of most of the species have reached the maximum sustainable yield (Radhakrishnan, 2011).

The studies on the growth parameters and stock assessment of deep-sea shrimp from Indian waters are restricted to two pandalid species, *H. gibbosus* and *H. woodmasoni* (Radhika, 2004). The growth and population parameters of deep-sea shrimps studied on other parts of the world include *H. laevigatus* from Hawaii waters (Dailey and Ralston, 1986), *Haliporoides sibogae* from Australian coast (Baelde, 1994), *Aristaeomorpha foliacea* from northwestern Ionian Sea (Donghia *et al.*, 1998), *Parapenaeus longirostris* from Montenegrin waters (Olivera and Slobodan, 2010), *Aristeus antennatus* in the Mediterranean Sea and from Balearic waters (Onghia *et al.*, 2005; Beatriz *et al.*, 2008), *Plesionika acanthonotus, P.edwardsii, P.gigliolii, P. heterocarpus* and *P. martia* from western Mediterranean and northern Aegean Sea (Company and Sarda, 1997; Vafidis *et al.*, 2008), *P. martia* (Maiorano *et al.*, 2002; Chilari *et al*., 2005; Cengiz *et al*., 2012), *P. antigai* (Campisi *et al.*, 1998), *P. edwardsii* (Santana *et al.*, 1997), *P. narval* (Thessalou-Legaki *et al.*, 1989; Gonzalez *et al*., 1997; Arculeo and Lo, 2011), and *P. semilaevis* (Nakahata *et al.*, 2008). Ohtomi (1997) observed that monthly growth rate of shrimp was synchronously correlated with moulting frequency. The higher value of asymptotic length in females was a common feature in deep-sea pandalid shrimp and has been observed for many species (Dailey and Ralston, 1986; Ohtomi, 1997; Colloca, 2002). King and Butler (1985) reported that deep-sea shrimps shows longer life span compared to shallow water species. A clear segregation on size and depth has been reported in species of the genus *Plesionika* (Company and Sarda, 1997; Carbonell *et al.,* 2003). The calculated life span for the small sized *Plesionika* species (*P. heterocarpus, P. gigliolii* and *P. acanthonotus*) was between one and two years, whereas the larger *Plesionika* species such as *P. martia* and *P. edwardsii* was between two and four years (Company and Sarda, 2000; Maiorano *et al.*, 2002).

1.3 Objectives of the study

- To identify various species of decapod crustaceans in the deep-sea shrimp fishery of Kerala coast
- To generate a detailed account on catch and species composition of deep-sea shrimps in the fishery of Kerala coast.
- To evaluate the economic performance of deep-sea shrimp trawlers operated off Kerala coast
- To study the biological aspects like length-weight relationship, condition factor, reproductive biology, feeding habits, growth parameters and stock assessment of deep-sea pandalid shrimp *Plesionika quasigrandis* Chace, 1985.

Chapter 2

Deep-sea decapod crustacean fauna in the fishery

2.1 Introduction

The order decapoda is the most species rich group of crustaceans, with various economically important and morphologically diverse species leading to a large amount of research (Toon *et al.*, 2009). The largest group of decapoda are the brachyura crabs with 6559 species and followed by shrimps (3877 species), in which majority are caridean shrimps with 3268 species (De Grave *et al.*, 2009). Radhakrishnan *et al.* (2012) provided a checklist of Penaeoid, Sergestoid, Stenopodid and Caridean shrimp fauna of India, which included 142 species under 43 genera of the suborder Dendrobranchiata and 295 species under 88 genera of the suborder Pleocyemata.

The occurrence and taxonomic account of deep-sea crustacean in the commercial landings from southern coast of India reported by Dineshbabu *et al.* (2001), Nandakumar *et al.* (2001), Rajan and Nandakumar (2001), Rajamani *et al.* (2003), Thirumilu and Rajan (2003), Radhika (2004), Pillai and Thirumilu (2007). Recently, Thirumilu (2011a) provided taxonomic details of lithodid crab *Paralomis investigatoris* off Chennai coast. Thirumilu (2011b) reported the occurrence of squat lobster *Munidopsis scobina* from east coast of India. Komai and Rajool Shanis (2011) described new species of deep-sea shrimp, *Parastylodactylus sulcatus* from Indian waters. Rajool Shanis *et al.* (2012) reported the occurrence of deep-sea pandalid shrimp *Plesionika adensameri* from Arabian Sea. Pillai and Thirumilu (2013) provided taxonomic account of the deep-sea shrimp

Glyphocrangon investigatoris from east coast of India. Rajool Shanis *et al.,* (2014) reported misidentification of deep-sea pandalid shrimp *P.quasigrandis* from Indian waters. Chakraborty *et al.* (2014) confirmed the occurrence of deep-sea shrimp *Oplophorus gracilirostris* from India waters on the basis of morphological as well as molecular studies.

This chapter deals with the taxonomic account of deep-sea decapod crustaceans in the fishery with emphasis on the most dominant species, *P.quasigrandis* and newly recorded/described species.

2.2. Materials and methods

Commercial deep-sea shrimp trawl landing centers such as Sakthikulangara, Vypin and Cochin Fisheries Harbour were visited to collect decapods samples for a period of three years from January 2009 to December 2011. Additional samples of *P. quasigrandis* were also collected from Tuticorin Fisheries Harbour (Tamilnadu) for comparative study. The samples were preserved in the 5% formalin. Measurements were taken using a digital caliper to the nearest 0.01 mm and the total length (TL) measured from the tip of rostrum to tip of telson and carapace length (CL) from the orbital margin to the posterior dorsal edge of the carapace. The identification and description of species in the present study are in accordance to Alcock (1901), Chace (1985), Suseelan *et al.*,(1989), Suseelan (1990), Chan and Crosnier (1991), Chan (1998), Poupin (2003), Komai (2004), Fransen (2006), Chan and Ng (2008). Specimens examined in the present study were deposited in the collection of National Marine Biodiversity Museum at Central Marine Fisheries Research Institute (CMFRI), Natural History Museum and Institute (CBM) Chiba, National Bureau of Fish Genetic Resources, Cochin Unit, Cochin, (NBFGR CH) and Pelagic Fisheries Division in Central Marine Fisheries Research Institute (CMFRI, PFD), Cochin, India.

2.3 Results

Twenty six decapod crustacean species were identified during the study and the details are presented in the Table 2.1. Shrimps were the most diverse group with nineteen species recorded followed by lobsters (3), crabs (2) and squat lobsters (2). Among shrimps, Penaeoidea were represented by five species in three families and caridea by fourteen species in seven families. Crabs consisted of two species in two families and lobster included three species in three families. The squat lobsters were represented by two families Galatheidae and Chirostylidae. The family with the highest number of species observed was Pandalidae (7) followed by Acanthephyridae (2), Penaeidae (2) and Solenoceridae (2).

2.3.1 Taxonomic status of *Plesionika quasigrandis* Chace, 1985

Infraorder: Caridea

Superfamily: Pandaloidea Haworth, 1825

Family: Pandalidae Haworth, 1825

Genus: *Plesionika* Spence Bate, 1888

Materials examined

Plesionika quasigrandis, NBFGR CH 1142, ovigerous female, CL 22.92 mm, CMFRI PFD CR 133–140, eight specimens, five female, CL 17.2–24.8 mm (three ovigerous and two non-ovigerous) three male, CL 18.9–23.2 mm, off Kollam, Kerala coast, India, 220–300 m depth, CMFRI PFD CR 141–146, six specimens, four female, CL 18.3–23.8 mm (three ovigerous and one non-ovigerous) two male, CL l19.1–23.6 mm, off Tuticorin, Tamil Nadu 200–280 m depth.

Table 2.1. List of decapod crustaceans recorded in the deep-sea shrimp fishery of Kerala

Family	Species
Shrimp	
Aristeidae	*Aristeus alcocki* Ramadan, 1938
Glyphocrangonidae	*Glyphocrangon investigatoris* Wood-Mason &Alcock, 1891
Nematocarcinidae	*Nematocarcinus gracilis* Spence Bate, 1888
Acanthephyridae	*Acanthephyra fimbriata* Alcock& Anderson, 1894
	Acanthephyra sanguinea Wood-Mason &Alcock, 1892
Oplophoridae	*Oplophorus gracilirostris* A. Milne-Edwards, 1881
Pandalidae	*Heterocarpus gibbosus* Spence Bate, 1888
	Heterocarpus woodmasoni Alcock, 1901
	Plesionika adensameri (Balss, 1914)
	Plesionika alcocki (Anderson, 1896)
	Plesionika quasigrandis Chace, 1985
	Plesionika martia (A. Milne-Edwards, 1883)
	Plesionika williamsi Forest, 1964
Pasiphaeidae	*Pasiphaea* sp.
Penaeidae	*Metapenaeopsis andamanensis* (Wood-Mason in Wood-Mason &Alcock, 1891)
	Penaeopsis jerryi Pérez Farfante, 1979
Solenoceridae	*Hymenopenaeus equalis* (Spence Bate, 1888)
	Solenocera hextii Wood-Mason &Alcock, 1891
Stylodactylidae	*Parastylodactylus sulcatus* Komai & Rajool Shanis, 2011
Crab	
Lithodidae	*Paralomis investigatoris* Alcock& Anderson, 1899
Portunidae	*Charybdis (Goniohellenus) smithii* MacLeay, 1838
Enoplometopidae	*Enoplometopus macrodontus* Chan & Ng, 2008
Lobster	
Nephropidae	*Nephropsis stewarti* Wood-Mason, 1872
Palinuridae	*Puerulus sewelli* Ramadan, 1938
Squat lobster	
Galatheidae	*Munidopsis* sp. Whiteaves, 1874
Eumunididae	*Eumunida funambulus* Gordon, 1930

Diagnosis

Rostrum overreaching well beyond scaphocerite, armed with 40–49 dorsal teeth, including 4–7 teeth on carapace above or posterior to orbital margin and armed with 31–40 ventral teeth. Posterior ten ventral rostral teeth corresponding to 6–8 dorsal teeth abdomen without posteromesial tooth or median dorsal carina on third somite, 4^{th} and 5^{th}somites with pleura tapering posteroventrally to strong tooth. Telson 1.2–1.4 times longer than sixth abdominal somite, with four pairs of dorsolateral spinules. Stylocerite sharply acute and with outer margin barely curving upward. Scaphocerite 4–5 times as long as wide. Third maxilliped without epipod, Penultimate segment 1.2–1.4 times longer than terminal segment. Pereiopods without epipods, carpus of first pereiopod 0.85–0.90 times as long as carapace. Second pereiopod sub equal with 19–32 articles. Dactylus of third pereiopod rather paddle shape and 0.33–0.14 times as long as propodus.

Misidentification of *Plesionika quasigrandis* as *Plesionika spinipes*

Plesionika narval group is generally considered to be a taxonomically complex species cluster. According to Chan and Crosnier (1991), *P. spinipes*, *P. grandis* and *P. quasigrandis* belongs to the *P. spinipes* subgroup within the *P. narval* group. The species in this subgroup possess the fourth abdominal pleuron pointed. These three species bear strong morphological similarity and this led to misidentification of *P. quasigrandis* in India as *P.spinipes*. The important morphological differences among the *P. spinipes*, *P. grandis* and *P. quasigrandis* are given in the Table 2.2.

Plesionika quasigrandis was originally described by Chace (1985) from Philippine waters based on materials from 245–320 m depths. *Plesionika quasigrandis* is nearly similar to *P. grandis* and Chace (1985) observed the variations barely in the number of rostral teeth on ventral part and the proportional length of the distal two segments of third maxillipeds (Table 2.2).

Table 2.2. Comparisons of morphological characters of *Plesionika spinipes*, *P. grandis* and *P. quasigrandis.*

Plesionika spinipes* Spence Bate, 1888	***Plesionika grandis* Doflein,1902***	***Plesionika quasigrandis* Chace, 1985 (Present study)**
Rostrum with 46–54 dorsal and 24–36 ventral teeth.	Rostrum with 26–51 dorsal and 19–35 ventral teeth.	Rostrum with 40–49 dorsal and 31–40 ventral teeth.
Posterior 10 ventral rostral teeth usually corresponding to dorsal teeth.	Posterior 10 ventral rostral teeth usually corresponding to 9–14 dorsal teeth.	Posterior 10 ventral rostral teeth corresponding to 6–8 dorsal teeth.
Stylocerite sharply acute and with outer margin not curved upwards.	Stylocerite sharply acute and with outer margin not curved upwards.	Stylocerite sharply acute and with outer margin barely curving upward.
Penultimate segment of third maxilliped 1.6–2times longer than terminal segment.	Penultimate segment of third maxilliped 1.55–1.85times longer than terminal segment.	Penultimate segment of third maxilliped 1.2–1.4 times longer than terminal segment.
Penultimate segment of third maxilliped 1.6–2times longer than terminal segment.	Penultimate segment of third maxilliped 1.55–1.85times longer than terminal segment.	Penultimate segment of third maxilliped 1.2–1.4 times longer than terminal segment.
Carpus of first pereiopod 0.85–05 times as long as carapace.	Carpus of first pereiopod 0.9–1 times as long as carapace.	Carpus of first pereiopod 0.85–0.90 times as long as carapace.
Dactylus of third pereiopod elongated and conical and 1/7–1/13 times as long as propodus.	Dactylus of third pereiopod elongated and conical or somewhat paddle shape and 1/4–1/7 times as long as propodus.	Dactylus of third pereiopod rather paddle shape and 1/3–1/7 times as long as propodus.
Telson 1.1–1.3 times longer than sixth abdominal somite.	Telson 1.1–1.4 times longer than sixth abdominal somite.	Telson 1.2–1.4 times longer than sixth abdominal somite.
Wider longitudinal red strips present on each side of abdomen.	Narrow longitudinal red strips on each side of abdomen.	No strips on the abdomen.

*Modified from Chan and Crosnier (1991)

In *P. quasigrandis,* the ventral teeth are distinctly more closely packed than those on the dorsal border, while the dorsal teeth are usually more closely set in *P. grandis*. *P.quasigrandis* differs from *P. spinipes* in several characters including morphometry, colour pattern and its geographical distribution. The pattern and range of rostral teeth is different in the two species. In *P. spinipes* the range of rostral teeth on the ventral side is between 24–36 and the posterior ten ventral rostral teeth usually corresponds to more than thirteen dorsal teeth, while in *P. quasigrandis* these are 31–40 and eight or less, respectively. A deep notch is present in the distal margin of the endopod of the first male pleopod of *P. spinipes,* which is absent in the same pleopod of *P. quasigrandis.* The body of *P. quasigrandis* is pale pinkish in color with no stripes on the abdomen (Plate 2.1), whereas *P. spinipes* has longitudinal stripes on each side of the abdomen. The stripes present in *P. spinipes* are slightly wider than those of *P. grandis* (Figure 21 and 22 in Chan and Crosnier, 1991).

Distribution

The shrimp species *P. quasigrandis* and *P. grandis* have a wide distribution in the Indo-west Pacific region. *Plesionika spinipes* is reported from Eastern Australia, Kai islands, north of New Guinea, New Britain, Chesterfield islands, New Caledonia, Loyal islands and French Polynesia; however its distribution is not extended to Indian waters.

2.3.2 New records from Indian waters

2.3.2.1 *Plesionika adensameri* (Balss, 1914)

Infraorder: Caridea

Superfamily: Pandaloidea Haworth, 1825

Family: Pandalidae Haworth, 1825

Genus: *Plesionika* Spence Bate, 1888

Material examined:

Plesionika adensameri, CMFRI ED. 2.4.3.3, one male (TL 9.8 cm, CL 1.9 cm), two female (TL 8.2–10.3 cm; CL 1.6–2.2 cm), Cochin Fisheries Harbour, Kerala (India), Arabian Sea, 2009, 200–300 m depth.

Diagnosis

Eye broadly subpyriform and ocellus longitudinally oval. Rostrum double curved with dorsal teeth distributed entire length, antennal spine well developed and reaching distal margin of basicerite; pterygostomain tooth distinct, smaller than antennal spine; stylocerite sharp, overreaching dorsal margin of first antennular segment. Third maxilliped long and slender, reaching beyond scaphocerite. Scaphocerite long and slender, 4.5 times as longer than maximal width.

Basal segment of antennular peduncle with small ventromesial tooth. First pereiopod reaching with chela and half of carpus beyond scaphocerite; second pereiopod reaching distal margin of first pereiopod; third, fourth, and fifth periopods similar, very long and slender. Second thoracic sternite unarmed; sixth thoracic sternites with prominent median elevation; seventh thoracic sternite broader than sixth, with prominent median elevation, larger than that of sixth. Abdomen without posteromesial tooth or median dorsal carina on third somite. Sixth abdominal somite less than twice as long as high. Exopod of third pleopod less than 0.66 as long as carapace. Telson as long as sixth somite, ending in distinct acute distal protruding tip. Uropods as long as telson, slender, exopod with movable distolateral spine.

Distribution

Red sea (Depth: 732–1308 m) Gulf of Aden (Depth: 457–549 m), Maldives (Depth: 494 m) and India (Depth: 200–300 m).

1.3.2.2 *Enoplometopus macrodontus* Chan and Ng, 2008

Infraorder: Astacidea

Superfamily: Enoplometopidae Saint Laurent, 1988

Family: Enoplometopidae Saint Laurent, 1988

Genus: *Enoplometopus* A. Milne-Edwards, 1862

Material examined

Enoplometopus macrodontus, CMFRI PFD CR 148, female, CL 70.4 mm, CMFRI ED 3.4.1.1, off Chavakkad (10°30’, 75°24’), Kerala, South West coast of India, Arabian Sea, September 2009, 320 m depth.

Diagnosis

Body is cylindrical, carapace pubescent with numerous long stiff setae on the chelipeds, pereiopods, abdomen and telson. The rostrum is elongated which overreaches beyond the base of the antennular peduncle, armed with four spines laterally. The carapace is with five median and one postcervical spine. There are two lateral spines, one intermediate spine and one supra-ocular spine on the carapace. The intermediate tooth as large as the supra-ocular spine extends nearly to the margin of the eye. The median spines are almost equal but with anterior most spines slightly smaller. The postcervical tooth smaller than median teeth and is well defined and extends beyond the cervical groove. Abdomen and telson with long stiff setae. Telson rectangular, slightly longer than wide bearing two pair of movable lateral spine and two pairs of movable postero-lateral spines. Uropod with protopodite divided into two lobes, endopod shorter than telson and bearing a postero-lateral spine.

Carpus and merus of first cheliped almost completely covered with large and small teeth along the margins except posterior 0.5–0.33 of dorsal margin of merus which is finely denticulate or smooth. Pereiopod 2nd to 5th sub-chelate. The cervical groove is inconspicuous and shallow, antennal spine large. Branchiostegal spine is present and small. The first pereiopod is long chelate and dorsoventrally compressed. The inner face of the chela is with four spines and the outer face is with tubercles. Outer margin of the propodus has 9–10 teeth and the inner margin 8 teeth, rest are tubercles. The pleura of the 2nd to 5th abdominal somites is bluntly pointed.

Distribution

Balicasag Island, Philippines (90–200 m depth), Sri Lanka and Arabian Sea, India (320 m depth).

2.3.3 New species of deep-sea shrimp

2.3.3.1 *Parastylodactylus sulcatus*

Infraorder: Caridea

Superfamily: Stylodactyloidea Spence Bate, 1888

Family: Stylodactylidae Spence Bate, 1888

Genus: *Parastylodactylus* Figueira, 1971

Material examined

Parastylodactylus sulcatus, Holotype: male (CL 9.3 mm), Southern Arabian Sea, offshore between Kollam and Cochin, south west coast of India, 09°04.5’N, 75°52.4’E, 350 m, 21 February 2010, CBM-ZC 10536. Paratypes: 1 male (CL 7.7

mm), same data as holotype, CBM-ZC 10537; 1 male (CL 7.9 mm), same data as holotype, CMFRI-E.D.1.7.1.1.

Description

Body moderately slender; integument moderately firm, glabrous on surfaces. Rostrum (Fig. 2.1A and Fig. 2.3A) elongate, slender, 2.2 times longer than carapace, slightly to somewhat curving dorsally in distal half; dorsal margin armed with 18–20 rather widely spaced, moderately small spines, including 6–7 on carapace, ventral margin with 6–8 moderately small spines. Carapace with low, but distinct postrostral ridge extending to mid length; dorsal margin in lateral view slightly sinuous; supraorbital tooth absent; infraorbital lobe prominent, far exceeding beyond antennal tooth, rounded distally, constricted at base, sharply buttressed on lateral face; antennal tooth moderately strong, directed forward; anterolateral margin between antennal and branchiostegal teeth strongly sinuous with deep concavity just inferior to antennal tooth; branchiostegal tooth relatively strong, overreaching antennal tooth; hepatic groove very deep.

Abdomen (Fig.2.1 B) dorsally rounded on every somite; posterodorsal margin of third somite somewhat produced posteriorly. First to fourth pleura rounded, fifth pleuron with small posteroventral tooth. Sixth somite 1.6 times longer than high and 1.9 times longer than fifth somite, posteroventral angle bluntly pointed, posterolateral process moderately strong, terminating in acute tooth. Telson (Fig. 2.3 B and C) tapering posteriorly to acute tip, bearing five pairs of dorsolateral spines and three pairs of terminal spines. Eye (Fig.2.1 C) subpyliform; cornea relatively small, distinctly shorter than and slightly wider than eyestalk; ocellus absent. Antennular peduncle (Fig. 2.1 A and D) moderately stout, not reaching mid length of antennal scale. First segment longer than distal two segments combined; stylocerite strongly compressed laterally, reaching distal one-fourth of first segment, abruptly tapering to slender spiniform tooth; small, forwardly directed process proximal to base of stylocerite. Second and third segments unarmed. Outer flagellum with thickened aesthetasc-bearing portion reaching distal lamella of antennal scale; inner flagellum falling short of tip of rostrum. Antennal peduncle (Fig. 2.1A, C and D) moderately stout. Basicerite with moderately strong distolateral tooth.

Antennal scale (Fig. 2.1 E) 1.1 times longer than carapace, very narrow (8.7 times longer than wide), curving laterally in proximal half; lateral margin concave, unarmed; distolateral tooth strong, wider than distal lamella at base, far overreaching distal lamella; distal lamella clearly defined, narrowly rounded. Mandible (Fig.2.2 A and B) without palp; incisor and molar processes not clearly separated, incisor process bearing eight acute, unequal teeth on mesial margin; molar process with uneven mesial face; cluster of numerous minute spinules on mesial margin between incisor and molar processes. Maxillule (Fig. 2.2 C) with subovate coxalendite; basialendite subovate, somewhat narrowing basally, mesial margin with double row of slender spines and stiff setae; endopod with subtruncate terminal margin bearing one long spiniform seta at mesial angle and one short, curved sub marginal seta.

Maxilla (Fig. 2.2 D) with coxalendite consisting of single lobe; basialendite divided in 2 lobes, proximal lobe subrectangular, distal lobe subtriangular; endopod slightly curved mesially, reaching nearly to distal margin of basialendite, bearing one seta on mesial margin and three apical setae; scaphognathite moderately broad, posterior lobe sub triangular, bearing long, flexed setae terminally.

First maxilliped (Fig.2.2 E) with thickened coxalendite; basialendite narrowly subovate; endopod falling short of distal margin of basialendite; exopod moderately narrow, flagellum arising at midlength of mesial margin of caridean lobe; epipods large, distinctly bilobed. Second maxilliped (Fig. 2.2 F) with two terminal segments articulated at distal margin of propodus, ventral segment longer than dorsal segment; propodus elongate, slightly widened distally; carpus very short, cup-shaped; merus and ischium fused, subequal in length to propodus, bearing row of stiff setulose setae on ventral margin; exopod flagellum-like, slightly overreaching distal margin of merus; coxa with rounded, membranous epipod and large podobranch consisting of lamellae of various size (Fig. 2.2 G and H).

Third maxilliped (Fig.2.3D) slender, overreaching distal end of antennal scale by about 0.7 length of ultimate segment; ultimate segment gradually tapering distally, subequal in length to penultimate segment, bearing two rows of long setulose setae on ventral margin; ultimate segment with one minute spine distolaterally and with two row of long setulose setae on ventral margin; articulation between ischium and basis clearly delimited; coxa (Fig. 2.3 E) with flattened, subcircular epipodonlateral face, without strap-like process; exopod absent. Pereopods moderately long and slender (Fig.2.3 F,G and H), only left third pereopod of holotype preserved.

Third pereopod (Fig. 3 F–H) slightly falling short of tip of antennal scale; dactylus 0.27 times as long as propodus, terminating in strong, clearly demarcated unguis, armed with seven accessory spinules noticeably increasing in length, distalmost spinule arising somewhat proximal to base of unguis, only slightly shorter than unguis; propodus about 12.0 times longer than wide, with two rows of slender spinules and tufts of short stiff setae on flexor margin; carpus 0.4 times as long as propodus, bearing 3 slender spines on lateral face ventrally; merus and ischium completely fused, bearing five spines in distal half, these spines increasing in size distally.

First pleopod with exopod distinctly longer than endopod; endopod (Fig. 2.2 I) strongly modified, tapering distally, mesial part folded ventrally, bearing thick covering of stiff setae and prominent slender spur arising at mid length of dorsomesial margin, lateral margin sinuous with sparse long stiff setae, appendix interna very short, located subterminally, bearing cluster of adhesive hooks. Second pleopod with appendix masculine sub equal in length to appendix interna (Fig. 2.2 J and K), bearing row of stiff setae on almost over entire length of mesial margin and one subterminal seta on lateral margin, both appendices arising at proximal 0.2 of endopod and reaching to mid length of endopod. Uropod (Fig.2.3 I) with moderately stout protopod terminating posterolaterally in acute tooth; endopod slightly shorter than exopod, gradually tapering distally; exopod with slightly sinuous lateral margin, bearing one stout spine just mesial to minute posterolateral tooth.

Etymology

From the Latin *sulcatus* (grooved), in reference to the characteristic very deep hepatic groove seen in this new species.

Distribution

Known only from the type locality in the southern Arabian Sea, off Kollam, Southwestern India, 350 m.

2.4 Discussion

Among the 26 decapod species observed in the fishery during the study period , only seven species of shrimps, *A. alcocki, H. gibbosus, H. woodmasoni, P. quasigrandis, P. martia, M. andamanensis, S. hextii* and one species of lobster, *Puerulus sewelli* were observed regularly in fishery. Other species were observed to be very less and rare in commercial deep-sea shrimp landings. The details of catch and species composition are discussed in the Chapter 3.

The present observation on the deep-sea decapods crustacean in fishery agreed with the results of earlier investigations conducted by both exploratory surveys and in commercial landings of south west coast of India (George and Rao, 1966; Mohamed and Suseelan, 1973; Suseelan, 1974; Thomas, 1979; Oommen, 1980; Suseelan *et al.*, 1989; Suseelan, 1990; Ninan *et al.*,1992; Dineeshbabu *et al.*, 2001; Rajan *et al.*, 2001; Radhika, 2004; Jayaprakash *et al.*, 2006; Kurup *et al.*, 2008). Despite extensive sampling, no specimens of the two earlier reported species, *P. ensis* and *Heterocarpus laevigatus* from the deep-sea shrimp fishery off Kerala (Radhika, 2004) could be observed during the study. There is no report on the occurrence of deep-sea shrimp *P. williamsi* from Indian waters after their first reports (Suseelan, 1990), this is the second documented report of this species from India.

Pandalid shrimps were the most diverse group in the deep-sea shrimps during the study. Twenty four pandalid shrimp species belonging to six genera was reported from India (Rajool shanis *et al.*, 2012). Species such as *Plesionika ocellus, P.bifurca, P.unidens, Chlorotocus crassicornis, Dorodotes reflexus* and *H. tricarinatus* from Indian waters were reported about hundred years back and there are no further reports of these species. *Heterocarpus ensifer* described based on collections of the RIMS '*Investigator'* from Andaman Sea by Alcock (1901) was later re-identified as *H. sibogae* De Man, 1917 by Suseelan (1990).

Shrimps of the family Aristeidae consist of one of the most valuable deep-sea shrimp resources. Even though aristeid shrimp such as *Aristeus semidentatus*, *A. alcocki*, *Aristaeomorpha woodmasoni*, *A. foliacea* and *Aristaeopsis edwardsiana* was reported from the south west coast of India during deep-sea exploratory surveys (Radhakrishnan *et al.*, 2012; Ganga *et al.*,), only one species, *A. alcocki* was observed in the fishery during the study. Generally most species of the family Aristeidae inhabited at depth zone of above 500 m (Alcock, 1901; Paulo *et al.*, 2006), this may be the reason for absence of these species in the fishery. Recently, Ganga *et al.* (2012) reported the high catch rate of aristaeid shrimp, *A. edwardsiana* off Trivandrum at depth of 950 m during exploratory survey.

On close examination of the morphological characters and colour pattern of *P. quasigrandis* collected during the study, it is confirmed that the species occurring in Indian water is *P. quasigrandis* and not *P. spinipes***.** The dorsal and ventral rostral teeth count of *P. quasigrandis* in the present study differs from the description provided by Chace (1985), Chan and Crosnier (1991), Hanamura and Evans (1996) and Fransen (2006). The taxonomic position of *P. grandis* has been disputed in relationship to *P. spinipes* (De Man, 1920; Chace, 1985). However the study conducted by Chan and Crosnier (1991) and Li and Komai (2003) observed that the two species are specifically distinct. The major difference between the two species is in the relative length of the dactylus of third pereiopod and the spacing of the rostral teeth. Chan and Crosnier (1991) and Fransen (2006) doubted the validity of

Pandalus (*Parapandalus*) *spinipes* reported by Alcock (1901) from Kanyakumari and the taxonomic description of the species provided by George and Rao (1966) from the southwest coast of India and suggested that the species in Indian waters may be *P. grandis* or *P. quasigrandis.*

The stylodactylid shrimp genus *Parastylodactylus* was established by Figueira (1971) to accommodate *Stylodactylus bimaxillaris* Bate, 1888. The genus is characterized by the absence of a palp on the mandible and the presence of arthrobranchs above the bases of the first to fourth pereopods in both males and females. New species, *Parastylodactylus sulcatus* appears closest to *P. bimaxillaris*, sharing the following diagnostic characters: carapace with eight or fewer postrostral spines; fifth abdominal pleuron at least occasionally with posteroventral tooth; sixth abdominal somite 1.6–2.0 times longer than high; telson with five pairs of dorsolateral spines; dactylus of third pereopod with strong distal accessory spinule, making dactylus clearly biunguiculate; and merus ischium of third pereopod lacking proximoventral spine. However, the new species can be readily distinguished from *P. bimaxillaris* by the longer rostrum exceeding twice the carapace length (versus usually less than 1.8 times as long), the absence of a supraorbital tooth, and the very deep hepatic groove and the markedly inflated hepatic region inferior to the hepatic grove on the carapace. Furthermore, in *P. sulcatus*, the branchiostegal tooth over reaches the antennal tooth, while in *P. bimaxillaris*, it extends as far as the antennal tooth. The third pereopod is relatively longer and more slender in *P. sulcatus* than in *P. bimaxillaris*. There are no previous records of species of *Parastylodactylus* from waters around India and the present record thus constituting the first of the genus for Indian waters.

The reef lobster *Enoplometopus macrodontus* and pandalid shrimp *Plesionika adensameri* were recorded for the first time from Indian waters. Lobster *E. macrodontus* was originally described from Philippine (Chan and Ng, 2008). *E. macrodontus* can be mistaken with the other Indo-West Pacific species *E. occidentalis* in certain colour patterns. Both have only one spot on the carapace, many white spots on tergites and pleura and plain atennular flagella. They can be distinguished from each other by the presence of only one white band on the large chelae and banded basal segments on the 2nd to 5thpereiopods in *E. macrodontus.* This species also closely resembles the Atlantic *E. callistus* in having two lateral teeth, one intermediate tooth, five median teeth and one post cervical tooth on the carapace, presence of disto-ventral spine on the Ischium of the third maxilliped and two lateral spines on the telson. Chan and Ng (2008) reported *E. macrodontus* having two pairs of lateral spines on the telson. The present specimen also has two pairs of lateral spines and two pairs of postero-lateral spines. Fransen (2006) suggested that report of *P. adensameri* from Gulf of Aden and Maldives need confirmation, since this species is a possible endemic of Red Sea. The present record from the southern Arabian Sea confirmed the occurrence of this species in Indian waters. The present specimens collected from west coast of India agree well with the descriptions provided by Chace (1985) and Fransen (2006).

Diversity of deep-sea decapod crustacean of Indian waters is largely unexplored. The newly described deep-sea shrimp *Parastylodactylus sulcatus* from off Kollam is the latest new deep-sea shrimp reported from Indian waters during the last few decades. Majority of the deep-sea shrimp species were described hundred years back based on the surveys of the RIMS *Investigator* and there are no further reports and description of many of these species. Detailed systematic studies coupled with molecular markers on this group from Indian waters are required to unravel their taxonomic status, species richness and geographical distribution.

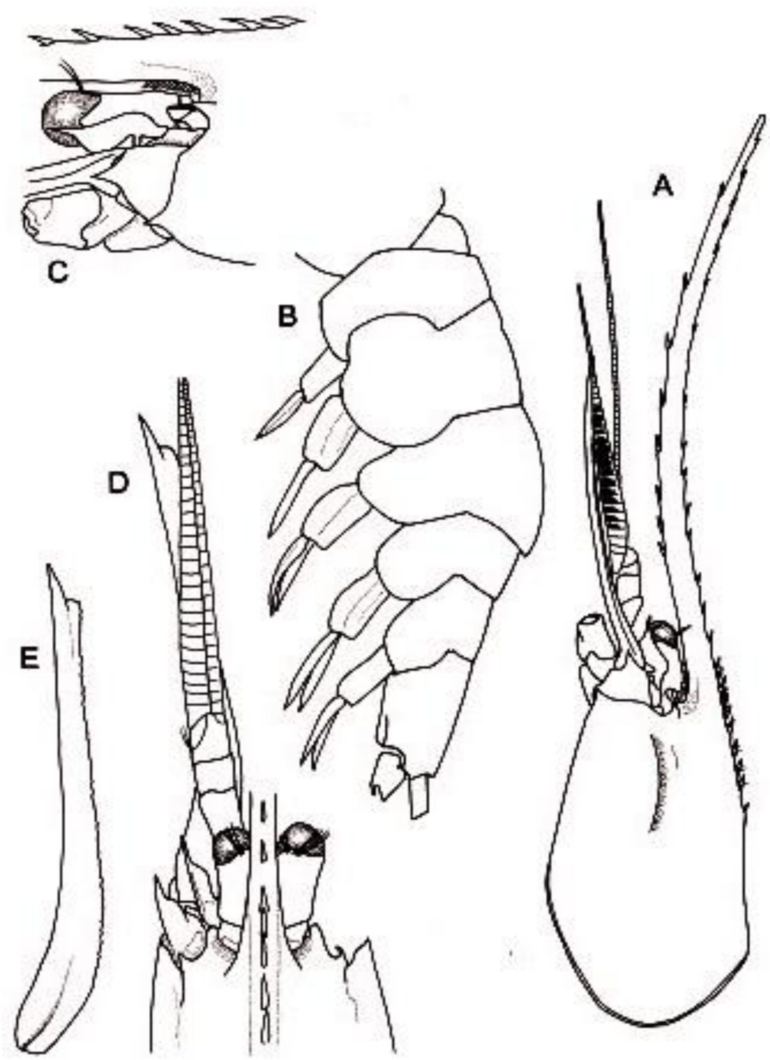


Figure 2.1. *Parastylodactylus sulcatus*, holotype, male. A, carapace and cephalic appendages, lateral view (left antennal flagellum missing); B, abdomen and pleopods, lateral view (telson and uropods broken off); C, anterior part of carapace, eye, and basal part of antennule and antennal peduncles, lateral view; D. anterior part of carapace and left cephalic appendages, dorsal view (setae omitted); E, left antennal scale, dorsal view

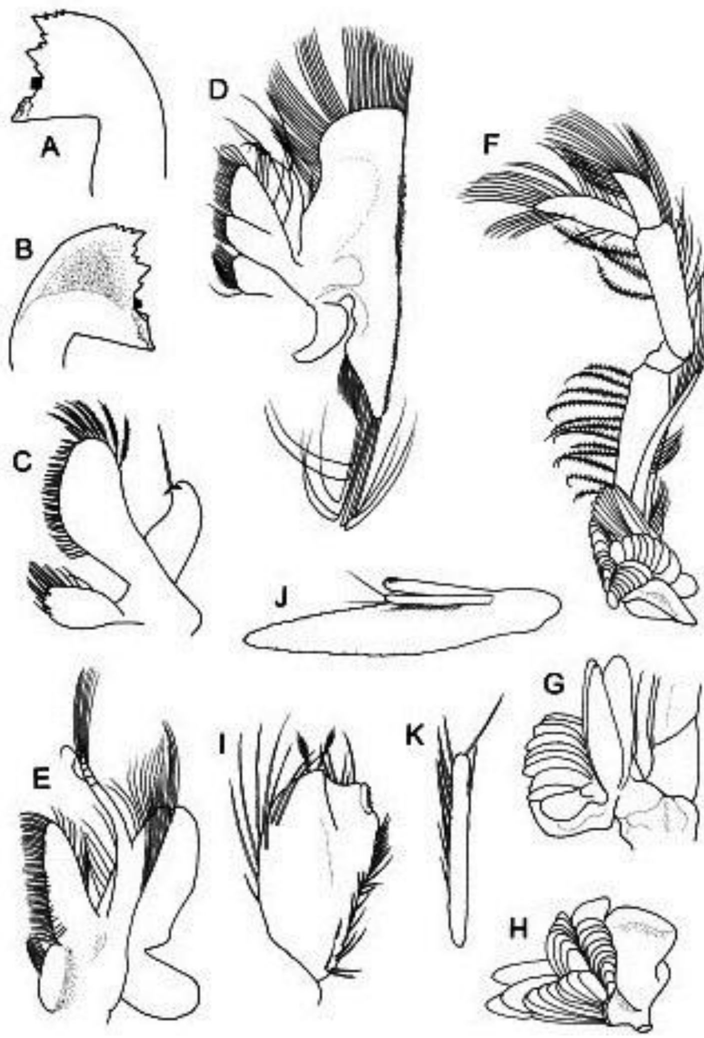


Figure 2.2. *Parastylodactylus sulcatus*, A–H, paratype, male; I–K, holotype, male. A, left mandible, outer view; B, same, inner view; C, left maxillule, outer view; D, left maxilla, outer view; E, left first maxilliped, outer view; F, left second maxilliped, lateral view; G, basal part of left second maxilliped, showing structure of epipod and podobranch, dorsal view; H, epipod and podobranch of left second maxilliped, ventral view; I, endopod of right first pleopod, ventral view; J, endopod of left second pleopod, ventral view; K, appendix masculina of left second pleopod, ventral view

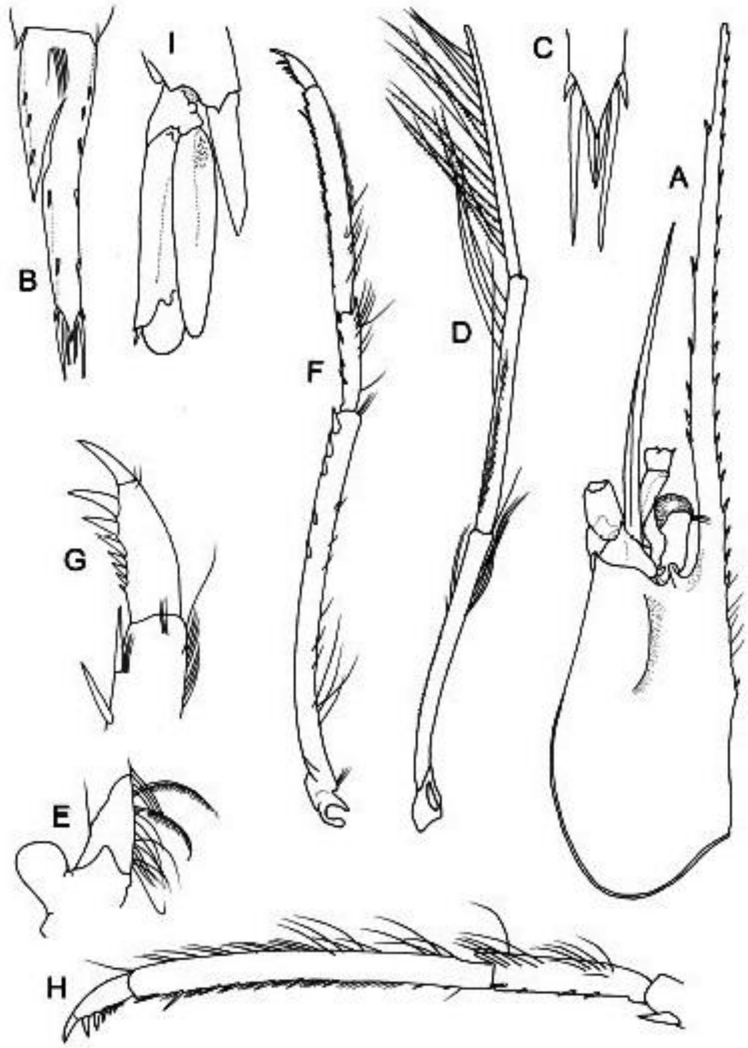
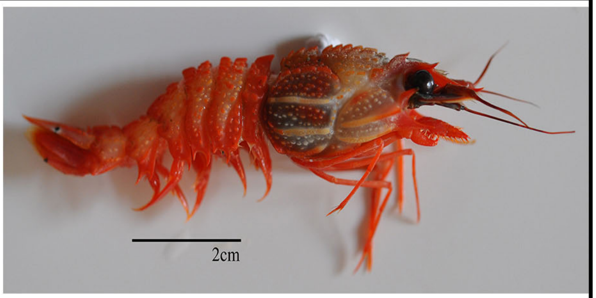


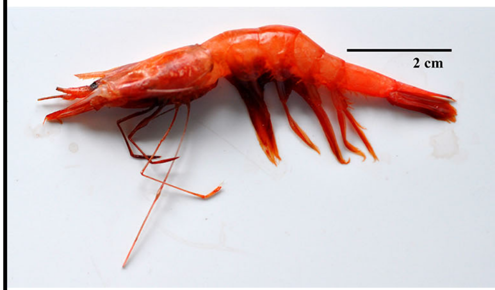
Figure 2.3. *Parastylodactylus sulcatus*, A–C, I, paratype, male , D–H, holotype, male. A, carapace and cephalic appendages, lateral view (antennule damaged, left antennal flagellum missing); B, telson, dorsal view (damaged); C, posterior part of telson, dorsal view; D, left third maxilliped, lateral view; E, same, basis and coxa, dorsal view; F, left third pereopod, lateral view; G, same, dactylus, lateral view; H, same, dactylus to carpus, lateral view; I, posterior part of sixth abdominal somite, telson and left uropod, lateral view

Plate 2.1

Aristeus alcocki



Glyphocrangon investigatoris

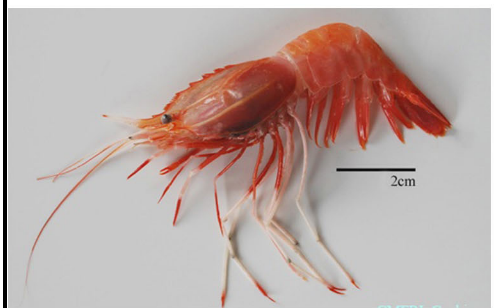


Nematocarcinus gracilis

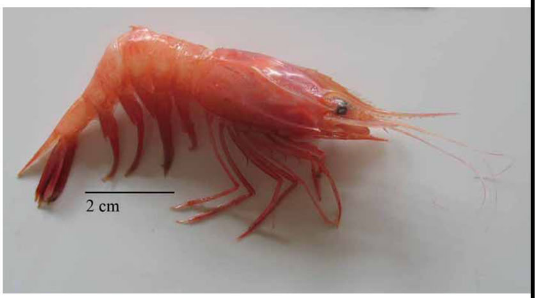
Acanthephyra fimbriata

Acanthephyra sanguinea

Oplophorus gracilirostris

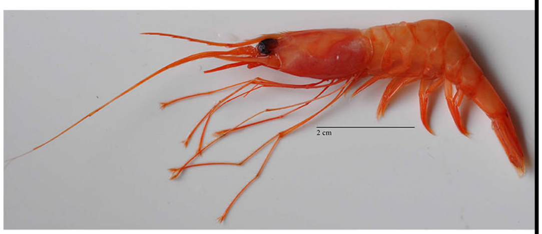


Heterocarpus gibbosus



Heterocarpus woodmasoni

Plesionika adensameri



Plesionika alcocki

Plate 2.2

Plesionika martia

Plesionika quasigrandis

Plesionika williamsi

Metapenaeopsis andamanensis

Hymenopenaeus equalis

Penaeopsis jerryi

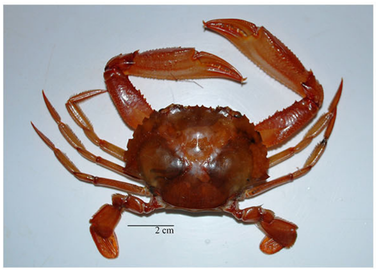
Solenocera hextii

Parastylodactylus sulcatus

Pasiphaea sp.

Plate 2.3

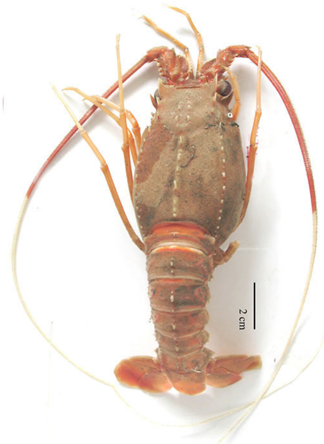
Paralomis investigatoris



Charybdis (Goniohellenus) smithii

Enoplometopus macrodontus

Nephropsis stewarti



Puerulus sewelli *Eumunida funambulus* *Munidopsis* sp

SECTION II

DEEP-SEA SHRIMP FISHERY OF KERALA

Chapter 3

Catch and species composition

3.1 Introduction

Shrimps contribute a significant portion of the exploited marine fishery resources of India and a highly valuable seafood commodity in foreign exchange earnings. In India, Kerala ranks third in total marine shrimp landing with an average catch of 50,514 t during the period 1985–2007 (Radhakrishnan, 2011). The present production of marine shrimp in Kerala estimated at 36,756 t which represent 89.7% of the total crustacean landings in the state (CMFRI, 2014). Landings of marine shrimp in Kerala coast showed significant fluctuations between 1990 and 2013 and reached maximum catch in 1994 (71,974 t) and minimum in 2013 (36,756 t) (Fig.3.1). In Kerala, 91% of total shrimp catch is contributed by penaeids and 9% by non-penaeid shrimps (Rao *et al.*, 2013). Owing to development of deep-sea shrimp fishing in Kerala since 1999, the non-penaeid shrimp catch increased and contributes 3.6% of all India shrimp landings (Radhakrishnan, 2011). This is due to pandalid shrimps are the major contributors to deep-sea shrimp fishery in Kerala. However before 1999, the share of non-penaeids shrimp was very less in the total shrimp landings of state (Fig.3.1).

Knowledge of new fishing grounds and modernization of the fishing techniques resulted the exploitation of deep-sea resources, especially shrimps which have the highest export value. Targeted deep-sea shrimp fishing in the Indian EEZ started during the early 1990s. The fishermen of Tamil Nadu had started to explore deep-sea shrimp resources off Tuticorin in 1989 during the lean fishing season.

Since 1999 and 2001, the fishermen of Kerala and Karnataka respectively are also engaged in deep-sea fishing by using modified conventional trawlers. Rajamani and Manickaraja (2003) reported the deep-sea shrimp fishery off Tuticorin coast for the period 1993–2002 with *H. woodmasoni* and *P. spinipes* as the dominant species, forming about 65% of total deep-sea shrimp landings.

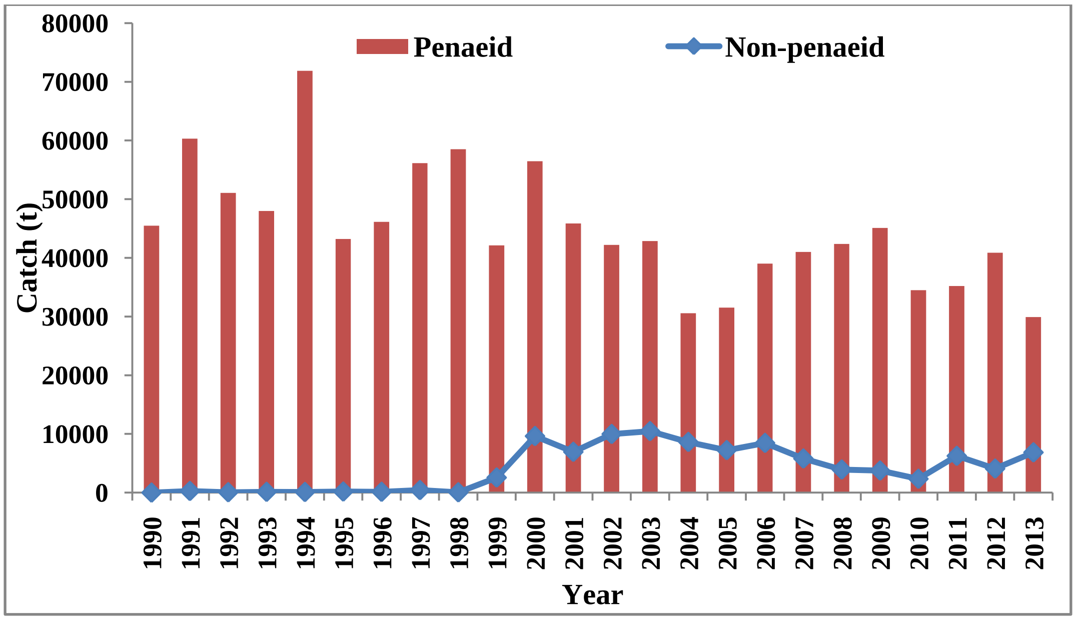


Figure 3.1. Penaeid and non-penaeid shrimp landings along Kerala coast during the period 1990–2013

Deep-sea shrimp fishery of Mangalore (Karnataka) was described by Dineshbabu *et al.* (2001) who reported *A. alcocki* ('red ring') as dominant species. Thirumilu and Rajan (2003) have given the detailed account of the fishery for deep-sea shrimps in Tamil Nadu and Pondicherry coast. Heavy landings of deep-sea shrimp dominant by *Parapandalus* species was reported of Andhra coast (Kakinada) during 2003 (CMFRI, 2004). Rajan *et al*. (2001) and Radhika and Kurup (2005) described the fishery and biological aspects of deep-sea shrimps landed along the Kerala coast. In the present study an attempt has been made to study the details of fishing operation, catch, species composition and landing trend of deep-sea shrimps in Kerala during the period 2009-2011.

3.2 Materials and methods

Deep-sea shrimp fishery of Kerala is mainly concentrated at three landing centers namely Sakthikulangara Fisheries Harbour, Cochin Fisheries Harbour and Vypin (Kalamukk and Murikkumpadam landing centers). Data on catch, effort and species composition of deep-sea shrimps was collected from these three landings centers during the period January 2009 to December 2011. The trend of coastal and deep-sea shrimp catch over the past ten years was analyzed the data obtained from the published reports of the Central Marine Fisheries Research Institute (http://eprints.cmfri.org.in). Monthly catch was estimated according to the methodology described by Srinath *et al.* (2005). Information on fishing ground, craft, gear, fishing details was collected by enquiries made with the fishers/trawl owners.

3.3 Results

3.3.1 Trawling operation

Along the Kerala coast there exist two types of deep-sea shrimp trawling operations, based on the targeted shrimp species group. One of the trawling operations targets the ‘red ring’, for which fishing operation are normally conducted at greater depths (>350 m) and other operation targets deep-sea shrimps which primarily constitutes pandalids and trawl operates at depths between 190-350 m. Fishing ground, duration of fishing trips, operation time varies with the targeted species group. Duration of fishing trips extends up to 15 days. While the fishing operation was conducted for the entire day for the trawlers targeting for the ‘red ring', the trawlers targeting other deep-sea shrimps operate only during the day time and the crew are engaged in tuna fishing using small long-lines during the night. Number of hauls ranged from 2–3 per day with duration of 4–5 hours. Deep-sea shrimp fishing operation extended between Kanayakumari and Ezhimala. Most important deep-sea shrimp fishing ground along the Kerala coast is off Kollam area (Quilon Bank) and about 81% of the deep-sea shrimp trawlers particularly targeting the pandalid shrimps were operating here. Some of the activities of deep-sea shrimp landings at Sakthikulangara, Vypin and Cochin Fisheries Harbours are shown in Plates 3.1 and 3.2.

3.3.2 Craft and gear

The entire fishing fleet engaged in the deep-sea shrimp fishery was built of steel and was well equipped with modern fishing devices. The trawlers are ranging in size from 18.2 to 21.9 m L_{OA}. Majority of the trawlers are powered with high horse power engine (300–420 hp) of Chinese made. The trawling speed of Chinese engine was found to be 4.5 nm/hr, which is twice the speed of normal indigenous engines. The trawlers had yard fabricated winches which were mechanical in nature and length of wire ropes in the winch ranging from 1800–2000 meter. Steel wire ropes with 10 mm diameter were used for trawling operations. The head rope and foot rope were made of 14.0 mm dia poly ethylene. The head rope's length of net ranged from 32–45 meters. Trawlers were equipped with V-shaped steel otter board, with its average weight of 75 kg each. Number of deep-sea shrimp trawl nets kept onboard ranged 3–5. Average code end mesh size is 24 mm. The fish hold capacity of trawlers was ranged from 10–15 t. Trawlers are outfitted with echosounder, GPS, wireless set, mobile phone, television set.

3.3.3 Landing trends

Total landings of deep-sea shrimp in Kerala was estimated as 8,579 t, 7,082 t and 10,490 t during the years 2009, 2010 and 2011 respectively. Deep-sea shrimp formed on an average of 21% of the total shrimp landings of Kerala with contributions of 17.6%, 19.2% and 25.3% during the respective years. Deep-sea shrimp landings trend in Kerala during the period 1999–2011was presented in the Fig 3.2.

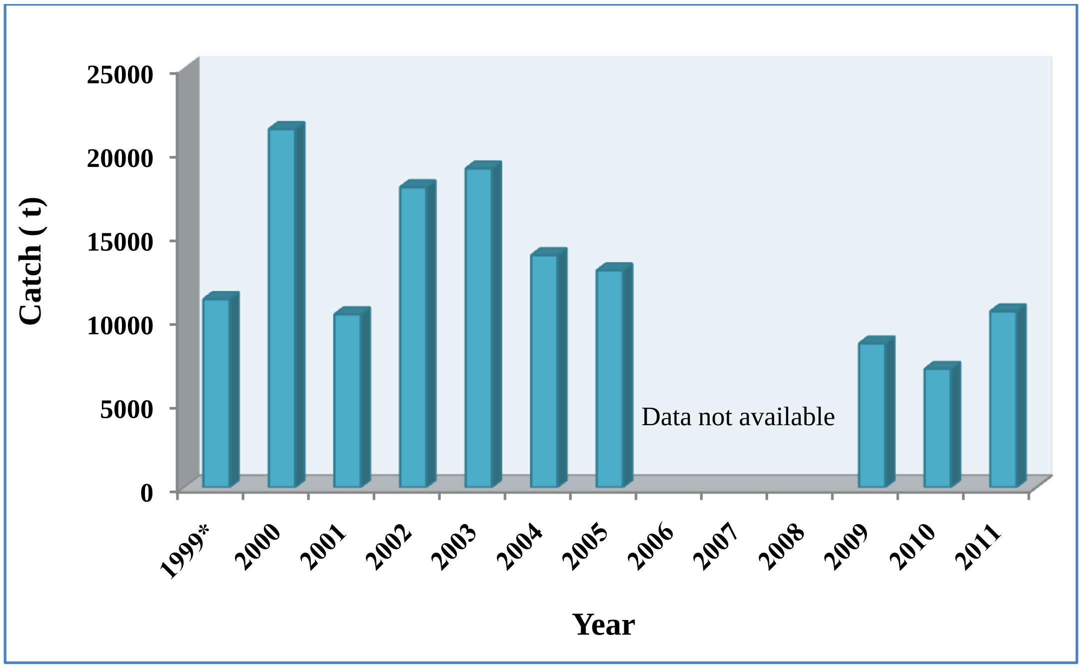


Figure 3.2. Deep-sea shrimp landings along Kerala during the period 1999–2011

Landings of the deep-sea shrimp have shown slight variations during the study period and the maximum landing observed in 2011 (10,490 t) and minimum in 2010 (7,082 t). Deep-sea shrimp landings during 2010 decreased by 17.4% from the previous year. However in the following years the landings showed 32.5% increase. More than 45% of the annual shrimp catches were landed during the last quarter of the year (October to December) and then the landings progressively decreasing toward the end of the season in May. Annual average catch rate of 'red ring' was 26.8 kg/hr, 26.3 kg/hr and 28.2 kg/ hr during 2009, 2010 and 2011 respectively. But in the case of other deep-sea shrimps the catch rate observed was comparatively low and recorded as 22.6 kg/hr, 20.9 kg /hr and 20.3 kg/hr in the respective years. Average catch rate of deep-sea shrimp during the period was 24.19 kg/hr.

3.3.4 Month wise landing

Deep-sea shrimp fishery season started from the end of August extending to the mid of May. Estimated monthly catch of deep-sea shrimp during the period 2009–2011 is given in the Table 3.1 and presented in Fig. 3.3. There was no fishery for deep-sea shrimps during June and July along Kerala coast. In 2009, the maximum and minimum landing was observed in November and August respectively.

Table 3.1. Month wise landings (in tonnes) of deep-sea shrimp along Kerala coast during the period 2009–2011

Month	2009 (t)	2010(t)	2011 (t)
January	925.7	901.4	1092.3
February	840.1	768.9	1417.8
March	840	845.3	1230.5
April	783.6	255.3	987
May	530.6	234.5	269.2
August	216	235.8	290.6
September	374.4	463.9	581.7
October	1052.2	763.7	996.8
November	1559.1	1447.5	1401.7
December	1457.2	1145.8	2222.5

*No deep-sea shrimp trawling operations during June and July

During 2010 and 2011, a similar trend was observed with a highest catch recorded in November and December and a minimum catch in May of the respective years. Landings was low occurred during August and May in all years of the study period. The contribution of the total deep-sea shrimp landing varied from a low of 2.52% in August 2009 to a maximum 21.19% in December 2011.

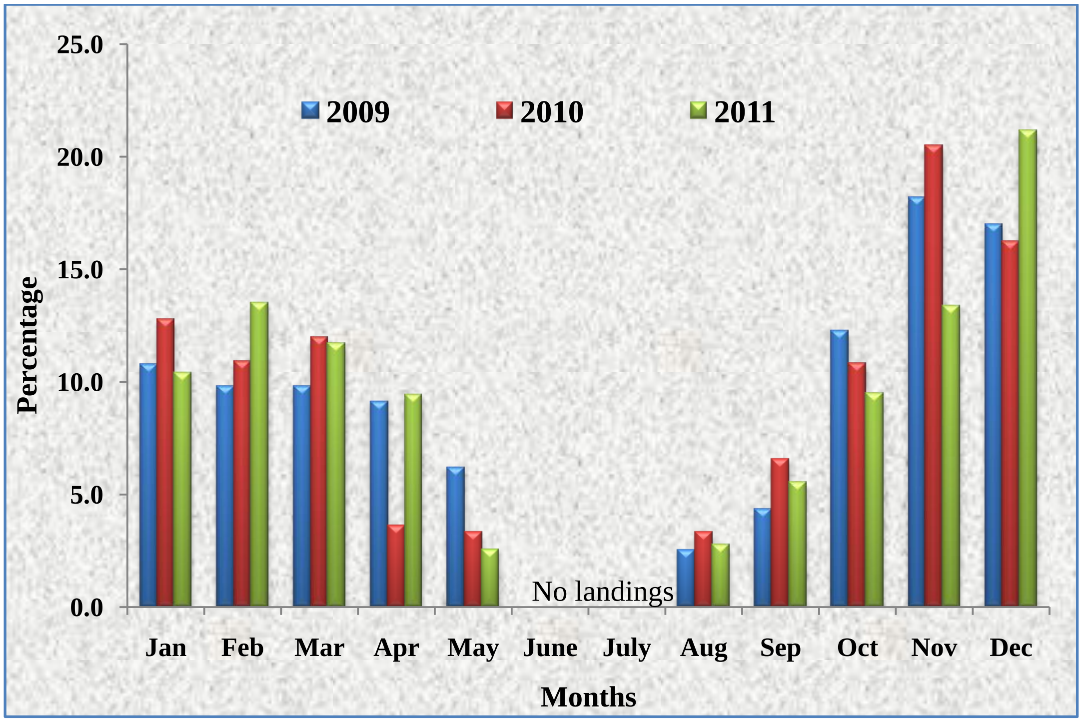


Figure 3.3. Month wise landings of deep-sea shrimp along Kerala coast during the period 2009–2011

3.3.5 Harbour wise landing

During the initial years of fishery, the landings of deep-sea shrimps were reported from more than ten harbours along the Kerala coast which subsequently reduced in the later years to three harbours, namely Sakthikulangara, Vypin and Cochin Fisheries Harbour. Presently deep-sea shrimp landings at these three landing centers together accounted for almost the entire fishery in Kerala. Total deep-sea shrimp landing in various harbours during the period 2009–2011 is depicted in the Table 3.2 and Fig 3.4. Estimated total landing of deep-sea shrimps in Sakthikulangara Fisheries Harbour was 5,708.4 t, 4,735.3 t, and 7,558.4 in the year 2009, 2010 and 2011 respectively which accounted for more than 68% of the total deep-sea shrimp landings of Kerala. Cochin Fisheries Harbour accounted for the major share of the 'red ring' catch and formed more than 38% of the total deep-sea shrimp landings in this harbour during 2009–2011. Pandalid shrimp *P. quasigrandis* was the dominant species at Sakthikulangara (27%) and Vypine (29%). Percentage contribution of 'red ring' at Vypine was comparatively less (7%). Percentage of catch contribution in Sakthikulangara Fishing Harbour increased to 72% during 2011, however in other two landing centers a decreasing trend was observed compared with last two years.

Table 3.2. Harbour wise landings (in tonnes) of deep-sea shrimp along Kerala coast during the period 2009–2011

Harbour	2009 (t)	2010 (t)	2011 (t)
Sakthikulangara	5708.4	4735.3	7558.4
Vypine	1270.7	1186.0	1248.7
Cochin Fisheries Harbour	1599.8	1140.7	1683.2

3.3.6 Species composition

Nineteen deep-sea shrimps were observed in the landings, of which seven species; *A. alcocki*, *H. gibbosus*, *H. woodmasoni*, *M. andamanensis*, *P. quasigrandis*, *P.martia* and *S. hextii* were dominant in the landings. The rest of the species observed were very low quantity in the landings and hence not considered in the catch estimation. Annual catch composition of the deep-sea shrimps in the fishery during the study period is provided in Table 3.3 and Fig. 3.5.

Pandalid shrimps were the major group in the fishery which represents nearly 54.7% of the total landings. During the study period , *P.quasigrandis* was the dominant species in the fishery and contributed 2,424.3 t, 1,818.9 t and 2,692.2 t in 2009, 2010 and 2011 respectively. Average monthly percentage of contribution of *P. quasigrandis* to total deep-sea shrimp landings ranged from 17% (August) to 39% (November). Second dominant species was *M. andamanensis* with an annual catch of 1,816.6 t, 1,710.3 t and 2,028.7 t in the respective years. 'Red ring', is the most valued species among the deep-sea shrimp and majority of the fishermen started selective harvesting of this species. As a result the landing of 'red ring' increased in the fishery, it contributed to18.8%, 21.2% and 24.7% during 2009, 2010 and 2011 respectively.

Table 3.3. Species wise landings (in tonnes) of deep-sea shrimp along Kerala coast during the period 2009–2011

Species	2009 (t)	2010 (t)	2011 (t)
A. alcocki	1613.9	1495.1	2591.5
H.woodmasoni	988.5	725.5	1038
H. gibbosus	1210.6	960	1632.9
P.quasigrandis	2424.3	1818.9	2692.2
P.martia	301.5	219.8	297.2
M.andamanensis	1816.6	1710.3	2028.7
S. hextii	223.5	132.5	209.7

Landings of *H. gibbosus* and *H.woodmasoni* have shown a slightly decreasing trend during the period 2009–2011. *Plesionika quasigrandis, M. andamanensis* and *A. alcocki* formed on an average 69.7% of the total deep-sea shrimp landings. Catch of *P. martia* and *S. hextii* together contributed only 5.3%. During the year 2011 catch of *P. quasigrandis* decreased and the catch of *A. alcocki* showed slight increase when compared with previous years.

3.4 Discussion

Along the Kerala coast five deep-sea shrimp species occurred regularly in the landings. Among these, *P. quasigrandis* was the most dominant species and accounted for 25.8% to 28.3% in the landing during the present study. From 1999 onwards *P.quasigrandis* comprised an average of 20% in the total deep-sea shrimp catch of Kerala. The species composition of deep-sea shrimps has noticeably changed since the last few years. Presently, 'red ring' represents about 22% of the total deep-sea shrimp production in Kerala and was the second dominant species during 2011. The earlier studies reported that 'red ring' contribution in the total deep-sea shrimp landings was below 10% (Rajan *et al.,* 2001; Radhika 2004; CMFRI 2004; CMFRI, 2005). This is probably because the 'red ring' is targeted more owing to bigger size and high market values. Proportion of *H. gibbosus* and *H. woodmasoni* in the fishery has drastically decreased from previous years and the current contribution of these species is 8% and 10% respectively. *Heterocarpus woodmasoni* was the dominant species (34%) in the fishery during the period 2000–2001 in Kerala coast (Rajan *et al.,* 2001). Radhika (2004) also reported the high percentage of *H. gibbosus* and *H. woodmasoni* in the fishery.

Average annual landing of deep-sea shrimp in Kerala coast during the study period was 8,717 t. The three years of the catch data series showed minimum catch value of 7,082 t during 2010 and highest in 2011. Annual deep-sea shrimp landing indicated an overall decreasing trend with landings fluctuating annually. In the initial period of deep-sea shrimp fishery (1999–2000) the landings of shrimp was estimated 23,426 t (Rajan *et al.,* 2001) which increased to more than 45,000 t during the latter period of 2000–2001 (Radhika and Kurup, 2004). Then the landings progressively decreased. The increase in landings in the initial years of deep-sea shrimp fishery coincided with an increase in fishing effort. Percentage contribution of deep-sea shrimps in the total shrimp landings in Kerala was high in 2011 (25.3%) and lowest in 2009 (17.5%) during the current study period. Fluctuations in the annual landings of deep-sea shrimp are mainly due to the availability of high value demersal fishes and cephalopods. Most of the trawlers are equipped with more than three types of trawl net for specific targets like deep-sea shrimps, cephalopods and other demersal fishes. When the availability of demersal species, especially cephalopods is high, it negatively reflected in the landings of deep-sea shrimp which are less preferred by the fishermen due to high market value of cephalopods. During the study period, lowest and highest cephalopods landing was recorded in 2011 and 2010 respectively along Kerala coast (CMFRI, 2009 and 2010).

A distinct seasonality was noticed in the deep-sea fishery. Even after a decade of fishing, seasonal variations in deep-sea shrimp fishery follows the same pattern. In Kerala, trawl ban period is during June and July (between mid June and July), after which most of the trawlers are engaged in the fishing for demersal fishes, cephalopods and coastal shrimps. Since October the availability of these resources are declining and during the lean fishing season more trawlers go for the deep-sea shrimp fishing.

Deep-sea shrimp fishing season in Kerala began at the end of the August and closed in the first/second week of May. Deep-sea shrimps were landed in all months apart from during June and July, when there was a ban on trawling operations and also due to unfavorable weather. November to February is the peak period for deep-sea shrimp fishery and accounting for an average of 70% of the annual landings. Rajan *et al.* (2001) and Radhika (2004) also reported the same period for the bulk landings of deep-sea shrimp along the Kerala coast.

In the total deep-sea shrimp landings, 68% were contributed by Sakthikulangara Fisheries Harbour and the previous studies also reported the high proportion of catch from the Sakthikulangara (Rajan *et al.,* 2001; CMFRI 2003; Radhika, 2004; CMFRI, 2005). Deep-sea shrimps have very less local market demand in Kerala and presently 99% is exported. Majority of the shrimp exporting companies are located on central Kerala which is the main reason for the landing of deep-sea shrimps being mainly limited to these three landing centers of Kerala. The deep-sea shrimp trawling operations are mostly concentrated in the 'Quilon Bank' consequently the landings also high in the Sakthikulangara. Catch of ‘red ring’ showed substantial increase in Cochin Fisheries Harbour and highest landing observed in 2010 (46%). Comparing with other two landing centers the price for ‘red ring’ is more and competitive at this harbour.

Deeps-sea shrimp resources are exploited only by trawlers in India. However in some parts of the world, shrimp traps are also used for the catching the deep-sea shrimps (Jeffrey, 1993; Darryl and Scott, 1998; Meargot *et al.,* 2007; William *et al*., 2014). Main advantage of traps is it can be easily operated in untrawlable deep-sea fishing grounds. Many deep-sea fishing grounds in Indian EEZ are rich in shrimps and lobsters, however majority of the these grounds are not suitable for trawling operations due to uneven and sloping bottoms (Observation in deep-sea exploratory survey at FORV *Sagar sampada* Cruise No. 281, 291 and

312). Ganga *et al.* (2012) reported the high catch rate for highly priced deep-sea aristaeid shrimp, *A. edwardsiana* off Trivandrum at depths of 950 m. However the trawling operation at these depth ranges is very difficult. Hence shrimp traps are very suitable for operating these types of fishing grounds. Recently William *et al.*, (2014) reported the good catch of deep-sea shrimps from Philippines Sea using shrimp traps. Hence it is suggested that the introduction of suitable shrimp traps in the potential deep-sea fishing grounds of Indian EEZ will help to exploit the deep-sea crustacean resources in a sustainable manner.

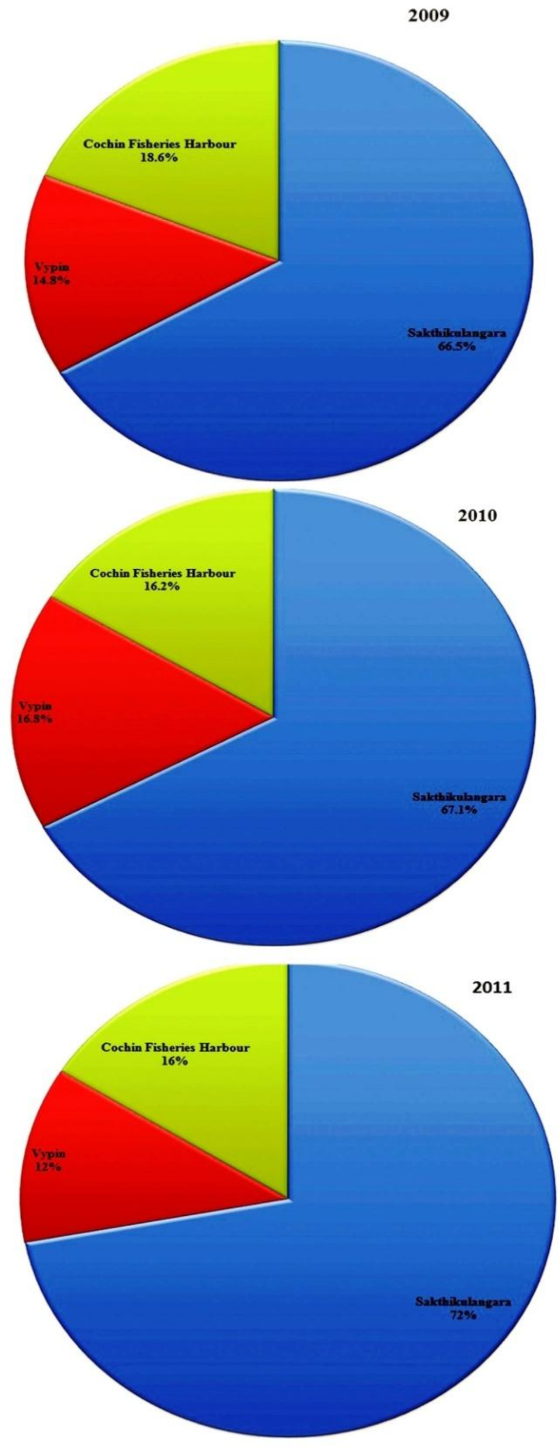


Figure 3.4. Percentage contribution of deep-sea shrimps in various harbours in Kerala (2009–2011)

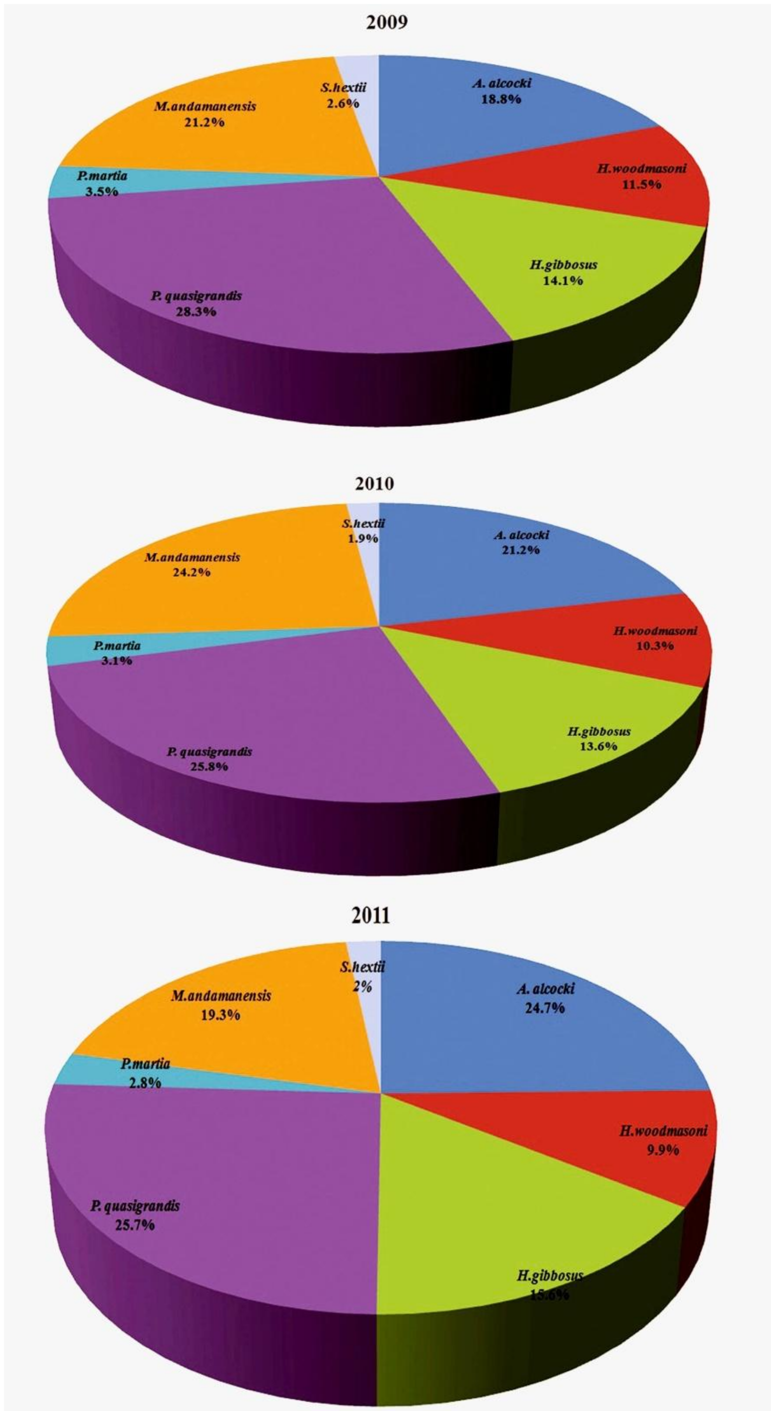


Figure 3.5. Annual species composition of deep-sea shrimps landings in Kerala (2009–2011)

Plate 3.1

Deep-sea shrimp landings at Sakthikulangara Fisheries Harbour

Landings of deep-sea shrimp, *Aristeus alcocki* at Cochin Fisheries Harbour

Landings of deep-sea shrimp, *Plesionika* spp. at Kalamukk landing centre (Vypin)

Plate 3.2

Deep-sea shrimp trawler at Sakthikulangara Fisheries Harbour

Heap of deep-sea shrimp, *Heterocarpus* spp. at Cochin Fisheries Harbour

Landings of deep-sea lobster, *Puerulus sewelli* at Sakthikulangara Fisheries Harbour

Chapter 4

Economics of deep-sea shrimp trawling operations

4.1 Introduction

The marine fishing sector has witnessed vast technological developments in both harvest and post-harvest sectors during the last few decades. Globally capture fisheries faced many issues and poor economic returns and high operational cost is one of the major problems. Economic research in the field of fisheries assumes significant role in forecasting appropriate policy measures and planning the future development schemes. In India fishing units of various craft-gear combinations run on profit as their earnings exceed, the break-even point mainly due to favourable price trend and even if due to nature of competition of open access marine fisheries, some of the less efficient units belonging to each category are forced to go out of the sector due to losses (Sathiadhas and Narayanakumar, 2001).

The economic performance of fishing operations is often affected by numerous factors such as fluctuations in revenue and catches, unexpected increases in the fuel cost and unfavourable weather condition. The depletion in the stock of fishery resources targeted by the mechanized units and the rising fuel prices pose serious threat to the economic viability of most of the mechanized fishing units. The economic performance of the fishing method is an important indicator, which decides the successful operation of the fleet. The investment in the fishing sector is mostly through private capital formation with government’s participation lie mainly in ports, harbours and similar major infrastructures.

The economics of fishing unit analysed by calculating the cost and earning of fishing unit per trip/ year. The economic evaluation of all types of fishing unit in the mechanised, motorised and non-motorised sectors have been studied by many researchers in India. Economic viability of different fishing methods has been studied by Sehara *et al.* (2000), Narayanakumar *et al.* (2009), Aswathy *et al.* (2011) and Geetha *et al.* (2014). The cost and earning of evaluation of mechanised trawlers has been analysed by many researchers (Devaraj and Smitha, 1988; Sathiadhas and Panikkar,1989; Sathiadhas *et al.*, 1992; Femeena and Sathiadhas, 2009) The economics of gill-netters, (Sehara and Karbhari,1989; Sathiadhas *et al.*, 1991) purse seiners and ring seiners (Sathiadhas *et al.*, 1993; Narayanakumar and Sathiadhas , 2005) also studied along the Indian coast .

The present study aimed to evaluate the economic efficiency of deep-sea shrimp fishing operation of Kerala and to estimate the profitability of deep-sea fishing operations. The economic efficiency is estimated by computing the annual cost and earnings of fishing unit per trip. The study also emphasizes the importance of addressing the issues faced by this sector with at most priority to improve economic efficiency.

4.2 Materials and Methods

A structured survey schedule was developed, pilot tested which solicited information detail on capital investment, fixed cost, operational cost and revenue. The data was collected from 90 trawl operators (owners and labourers) operating in Sakthikulangara, Vypin and Cochin Fisheries Harbours during the period January 2010 to December 2011. Percentage and tabular analysis was done to analyse the economics of deep-sea shrimp fishing operations. The following computations were carried out to assess the various parameters of economic efficiency.

Total cost= Fixed Cost + Operating Cost

Net Profit = Revenue – Total Cost

Net Operating Income =Revenue – Operating Cost

Rate of Return = Net Profit/ Total Cost

Profitability Ratio = Net Profit/ Operating Cost

Net Profit Ratio =Net Profit/ Revenue

Operating Ratio = Operating Cost/Revenue

In order to assess the different problems perceived by the trawl owners and fishermen the Garette Ranking Technique (Garrette and Woodworth, 1969) was employed to rank the problems in deep-sea shrimp fishing as expressed by the trawl owners and labourers. The order of merit given by the trawl owners was transmitted into scores. For converting the scores assigned by the trawl owners and labourers towards the particular problem, percent position was worked out using the formula.

$$\text{Percent Position} = 100\,(R_{ij} - 0.05)/\,N_j$$

Where,

R_{ij} = rank given for the i^{th} problem by the j^{th} trawl operator

N_j = number of attributes

The primary purpose of this methodology employed was to collect qualitatively accurate data than quantitative means, with a view to being able to put forward advisory and management strategies based on reliable information.

4.3 Result and discussion

The data collected from the research locations were tabulated and evaluated. The details of fishing operation and craft and gear discussed in the Chapter 3. There exists two types of deep-sea shrimp trawling operations in Kerala coast, based on the targeted shrimp species group. One for ‘red ring’ (*Aristeus alcocki*), for which fishing operation are normally conducted at greater depths (> 350 m) and others targets deep-sea shrimps which primarily constitutes pandalid shrimps and inhabited at a depth zone of 190–350 m. The results and discussion are given below under the following sub-topics.

4.3.1 Capital Investment

The average capital investment for shrimp trawlers worked out to be Rs.42.85 lakhs. The capital investment consists of the cost of construction of hull, cost of engine, gear and other accessories. It was found that all trawlers are equipped with echo sounder, GPS, wireless set, mobile phone, television set and other state of the art gadgets. More than 50% of the deep-sea shrimp trawlers were less than five years old. It was deduce that the cost for engine contributed to 24% of the total capital investment.

Table 4.1. Average capital investments of deep-sea shrimp trawlers operated along Kerala coast

Items	Value (RS)
Hull	27,32,500
Engine	10,10,167
Gear	1,72800
Winch	98,500
Echo Sounder	85,262
Others	1,86,216
Total	42,85,445

Majority of the trawlers are powered with high horse power engine (300–420 hp) of Chinese origin. The trawling speed of Chinese engine was found to be

4.5 nm/hr, which is twice the speed of normal indigenous engine. The price of Chinese engines ranged from Rs.12–16 lakhs but with no after sales guarantee on the engine and facing difficulties in maintenance and purchase of spares. The details of the average capital investment are listed in Table 4.1 and Fig.4.1. The ownership of the trawlers targeted for deep-sea shrimp fishery shared ownership with 79%. The details of the year of purchase of deep-sea shrimp trawlers are given in the Fig.4.2. More than 50% of trawlers are purchased after the year 2007.

4.3.2 Fixed cost

The average annual fixed cost was computed by employing the elements of capital investment, insurance and interest on working capital. The value of hull, engine and gear depreciated at the rate of five percent, seven percent, and thirty percent respectively. Annual depreciation was calculated using the straight line method of computation using the cost of purchase, its salvage value (residual value) and its expected life in years was used.

Table 4.2. Average annual fixed cost of deep-sea shrimp trawlers operated along Kerala coast

Items	Red ring (Rs)	Other deep-sea shrimp (Rs)
Hull	1,36,625	1,36,625
Engine	70,712	70,712
Gear	51,840	51,840
Accessories	36,998	36,998
Interest on working capital	10,470	7,095
Insurance	1,28,563	1,28,563
Total	4,35,207	4,31,833

The interest on working capital (5%) was worked out to be Rs. 10,470 and

Rs. 7,095 for targeting of 'red ring' and other shrimp respectively. The details of the fixed cost are furnished in Table 4.2. The average annual number of fishing trips for trawler targeting 'red ring' was 29 and other deep-sea shrimps was found to be 34.

4.3.3 Operational cost

The main components of operating cost such as fuel, ice, auction charges, provisions, marketing charge, allowance, crew share, maintenance cost and their percentage of contribution is given in Fig.4.3 and Fig.4.4. The average operational costs per trip were found to be Rs. 2.11 lakhs and Rs.1.47 lakhs for 'red ring' and other shrimp respectively (Table 4.3). It was found that the operational cost of trawlers targeting 'red ring' was found high on an account of day-night fishing operation, lengthy fishing days and distance of fishing ground.

Table 4.3. Average operational cost (per trip) of deep-sea shrimp trawlers operated along Kerala coast

Particulars	Red ring	Other deep-sea shrimps
Fuel	1,18,017 (55.83)	78,952 (53.44)
Oil	1,980 (0.94)	1,010 (0.68)
Ice	14,170 (6.70)	10,355 (7.01)
Auction	12,070.5 (5.71)	8,316 (5.63)
Provisions	7,526 (3.56)	6,132 (4.15)
Maintenance	3,250(1.54)	2,900 (1.96)
Bata	7200 (3.41)	5600 (3.79)
Crew Share	45,468.4 (21.51)	32,843(22.23)
Others	1,690 (0.80)	1,640 (1.11)
Total	2,11,372	1,47,748

*Figures in parenthesis indicate percentage to total

The total operational cost indicated that the cost of fuel was the maximal component contributing around 55% of the total costs, this was followed by the crew share (22%) and then by provision for ice (7%). Percentages were found to be high when studied in comparison with the case of multiday trawlers operating less than 200 meter depths, where the fuel cost contributed to 49% (Aswathy *et al.,* 2011). The frequent price hike of diesel has an adverse effect on the sector. Mismatch in the market price of the deep-sea shrimp in relation with the increase of fuel price. The rate of 'red ring' was found to be Rs. 80–100 /kg a decade back (Rajan *et al.,* 2001) while presently the rate is Rs. 110–140/ kg, but in the case of diesel price the rate increased more than double during the same period. The auction charge varies depending on harbours and generally differs from 5–7% of the total catch. Ice is crushed using crushing machine at the harbour and stored in the fish hold of the trawler. The trawler targeting 'red ring' and other deep-sea shrimps carries 250–300 and 200–250 block ice respectively. The deep-sea trawlers carry 2000–4000 liters of water for drinking and cooking purpose.

Crew payments are based on an agreed share of net revenue between the owner and the crew members. Fishing crew is paid a share of the returns and daily allowance (Bata). The daily allowance of one crew member is around Rs.100–150 per fishing day. After reducing the operational cost such as fuel, auction, provisions, marketing, berthing charges from the net revenue, 65% of the remaining revenue goes to the boat owner and the rest 35% is divided among the crew members. Crew members of some deep-sea trawlers engaged in the tuna fishing at night using small long-liners, earn from both tuna and its by-catch, this is again distributed equally among the crew members.

4.3.4 Gross Revenue

Catch composition and revenue from the deep-sea shrimp operation is given in the Table 4.4 and Table 4.5. The major catch targeting 'red ring' is *Aristeus alcocki*, whereas in the case of other deep-sea shrimps the targeting species includes *Plesionika quasigrandis, Heterocarpus gibbosus, H. woodmasoni* and *Metapenaeopsis andamanensis.* It was found that the trawlers that target 'red ring' often catch large quantities of deep-sea sharks as by-catch. The landing price of deep-sea shrimp fluctuated with species, size and quality. The 'red ring', *A. alcocki* is the most valued species among deep-sea shrimp landing in Kerala and *P.quasigrandis* is the most dominant species in the landings. The average revenue per trip has been estimated at Rs. 3,03,554 for 'red ring' and Rs. 2,02,607 for other deep-sea shrimps.

Table 4.4. Average catch, unit rate and revenue (per trip) of deep-sea shrimp trawlers targeting for 'red ring'

Species	Quantity (Kg)	Average Rate/kg	Revenue (Rs)
A. alcocki	2383	108	2,57,364
Shark	298	155	46,190
Total	2574	-	3,03,554

Table 4.5. Average catch, unit rate and revenue of deep-sea shrimp trawlers targeting deep-sea shrimps other than 'red ring'

Species	Catch (kg)	Rate per kg	Revenue (Rs)
Plesionika spp.	1238	45	56,948
M. andamanensis	1121	45	50,445
Heterocarpus spp.	1012	60	59,334
Tuna	205	110	22,550
Shark	86	155	13,330
Total	3662		2,02,607

4.3.5 Economic efficiency parameters

The economic efficiency of deep-sea shrimp trawling for 'red ring' and other shrimps are listed in Table 4.6. The analysis indicated that the average fixed cost of 'red ring' to be Rs. 15,007, which accounts for 6.68% of the total cost, thus the variable cost incurred in the operation is 93.32% of the total cost and the operating cost was computed to be Rs. 2,09,391, which yields to a total cost of Rs. 2,24,398. The revenue generated through this operation is Rs. 3,03,554 with a net profit gain of Rs. 79,156 and Rs. 94,163 being the net operating income. In comparison, the average fixed cost of other deep-sea shrimp was found to be Rs. 12,701 which accounts for 7.97% of the total cost, the variable cost here being 92.03%. The operating cost was estimated to be Rs. 1,46,737 giving rise to a total cost of Rs.1,59,438 and generating revenue of Rs. 2,02,607. The net profit from other deep-sea shrimps was found to be Rs. 43,169 and the net operating income was Rs. 55,870. The above values are graphically represented in Fig.4.5.

Table 4.6. Economic efficiency indicators of deep-sea shrimp trawlers (per trip)

Efficiency parameters	Red ring	Other deep-sea shrimp
Average Fixed Cost (Rs)	15,007	12,701
Operating cost (Rs)	2,09,391	1,46,737
Total cost(Rs)	2,24,398	1,59,438
Revenue (Rs)	3,03,554	2,02,607
Net Profit (Rs)	79,156	43,169
Net Operating Income (Rs)	94,163	55,870
Rate of return	0.35	0.28
Profitability Ratio	0.38	0.29
Net profit Ratio	0.26	0.21
Operating Ratio	0.69	0.72

The operating ratio worked out to be 0.69 and 0.72 for trawlers targeting for 'red ring' and other deep-sea shrimps respectively, indicating that 69% and 72% of the net revenue generated is used in its operating charge. Average operating ratio of deep-sea shrimp trawlers was 0.70, which is high compared to coastal multiday trawlers (0.58) (CMFRI, 2010). Rate of return, profitability ratio and the net profit ratio for the ‘red ring’ is estimated to be 0.35, 0.38 and 0.26 respectively. While for the other deep-sea shrimps it was found to be 0.28, 0.29 and 0.21. (Fig.4.6).

4.3.6 Problems and Prospects

In order to analyse the problems encountered in the deep-sea shrimp fishing operations, 90 trawl owners and labourers were interviewed using a pretested interview schedule. The important problems opined by them, were listed, ranked and on the basis of the ranks assigned, Garette ranking technique was employed to analyse the problems related in the deep-sea fishing operations. The results of the Garette ranking technique are furnished in Table 4.7. The results indicated that the high operational cost, high risk and efforts, lack of trained and skilled persons, low market price realisation, abundance of discards, poor quality of shrimps, low level of technology were the major problems encountered in the deep-sea shrimp fishing operations .The highest score of 81.43, is for the high operation cost followed by the score of 80.95 for the low market price of deep-sea shrimps and the lowest score (17.14) for low level of technology.

The high cost of operation is one of the major problems faced by the deep-sea shrimp fishery sector which was ranked first among the constraints faced by deep-sea shrimp trawlers. Trawl owners ranked that the deep-sea shrimp fishery is more expensive comparing with coastal fisheries and the high operational cost is the prime reason for the economic inefficiency of deep-sea shrimp trawling operations. The major operational components in trawlers are fuel charges. The fuel share constitutes about 56% of total operational cost in deep-sea trawlers. Frequent hike of the price of the diesel had badly affected this sector. In contrast with the hike of fuel price there is no increment in the market price of deep-sea shrimps. The cost for ice, water, provisions and maintenance charge is also higher in trawlers operating in deep-sea. Discoloration in the deep-sea shrimps is rapid when comparing with coastal species. Storing the shrimps in the fish hold of the trawler with good amount of ice is the better method for avoiding the discolouration. So deep-sea trawlers need to keep more ice in the fish hold and it is also increase the operating cost of the trawler.

Table 4.7. Analysis of the problems in deep-sea fishing operations-Garette Ranking Technique

Sl.No.	Parameter	Score	Rank
1	High cost of operation	81.43	I
2	Low market price realisation	80.95	II
3	High risk & effort	70.95	III
4	Lack of skilled persons	36.67	IV
5	Poor quality of shrimps	31.9	V
6	Abundance of discards	30.95	VI
7	Inadequate technology development	17.14	VII

The market rate of deep-sea shrimp is comparatively low due to low meat yield realization. The overall average yield of meat content in deep-sea shrimps is lower than that of coastal shrimps. The average yield of meat of deep-sea shrimp is 36% whereas in coastal shrimp the yield was 64% (Sachindra *et al.,* 2006). In total deep-sea shrimp landings 99% were exported and the local market demand is very low. One of the major quality problems in the deep-sea shrimp is its rapid discolouration due to melanosis and it is observed that the melanosis is one of the problems affecting the market value of deep-sea shrimp in international markets (King, 1988). Black colouration is also caused due to inaccurate icing and prolonged storage in the fishhold of the boat. Deep-sea shrimps especially in the case of pandalid have a little sweet taste and this may be one of the reasons for less local market demand in Kerala while this has high demand in Japan. Due to sweet taste and sticky texture of deep-sea shrimps the Japanese consume them raw (King, 1988).

The deep-sea shrimp trawling operations often generate huge proportion of by-catch fishes which ranges from 20–40% and sometimes exceeded more than 80% (Pillai *et al.*, 2009). Majority of by-catch fishes are dumping to the sea, except for the sharks and few fins fishes. However in Tamilnadu since the fishing operation was done for single day it was profitable to get back the by-catch from the sea, utilize either for fish meal production or human consumption. But in the case of deep-sea shrimp fishing operation in Kerala it is not profitable considering the huge cost of ice and storage space for the by-catch fin fishes. Pillai *et al.* (2009) has identified 57 deep-sea fish species from deep-sea shrimp trawlers operating off Kollam. Unfamiliar appearance, taste and texture of deep-sea fishes caused the less market preference of this resource. Presently the utilization of discards in India is very less and mainly used for production of fish meal and fertilizer. The biochemical analysis indicated that many of the deep-sea fishes with high protein content and low fat (Noguchi, 2001; Suseno *et al.,* 2010; Manju *et al.,* 2011). As the per capita protein availability far below the recommend level in India (Zynudheen *et al.,* 2004) the every effort should be made for utilization of by-catch and discard fishes. So there exists a vast scope for expansion of value added products from deep-sea fishes for ensuring nutritional security. The development of economically viable post harvest technology and value addition of deep-sea by-catch fin fishes would help to utilize these resources and would support fishermen to earn more income. Recent studies have shown that marine fishes are rich sources of bioactive peptides (Kim and Wijesekara, 2010; Su, 2011; Sampath *et al.*, 2012; Blanca and Miguel, 2013; Khora, 2013**)**. A variety of bioactive compounds have been extracted from the marine discard fishes with potential nutraceutical and medicinal values. In addition there exist scope to utilize the discards for the production of collagen, silage, gelatin, fish mince, hydrolysate, fish oil, surumi etc.

Off late, the research institutes had located many new deep-sea fishing grounds based on the deep-sea exploratory surveys. The fishermen are unaware of these new fishing grounds. However, a holistic system should be developed with government initiatives at the centre to disseminate fishing leads to fishermen and the shifting of operation from the existing fishing grounds to newly located deep-sea fishing grounds which also help to reduce fishing pressure on existing ground. Exploratory surveys for new fishing areas to be continued consequently map the potential fishing ground on a GIS platform and the data should be provided to the fishermen. The information on availability of such resources are to be regularly monitored and the information need to be passed on the fishermen and which would significantly increases the catch and revenue and thereby ensuring optimal utilisation of fishery resources.

The occurrence of fishable concentrations of deep-sea resources together with stagnating coastal production necessitated the need to recognize the deep-sea fishing as a priority area for developing the industry. The study on the existing marketing system indicated that the marketing system is dismal without any forward or backward linkages.

The deep-sea fishing operations are very risky since the fishing ground is far-flung from the coast and the fishing voyage extended up to more than 15 days duration. Climate condition of oceanic waters is also not favorable for deep-sea shrimp trawling operation day in and out. The deep-sea shrimp fishery sector needs more skilled and trained crew because of this reason. Most of the crew members in the deep-sea shrimp trawlers are from Thoothoor and nearby areas of Kanyakumari district, who had inherited their technical knowhow and experience from their forefathers. However the present generation not that much involved in the operations due to their interest towards better employment opportunities and moving out of fisheries sector. Thus there is an immediate need of trained persons in providing suitable training and scientific knowledge to fishermen for venturing into deep-sea fishery operations.Most of the deep-sea fishing grounds were in international shipping channel area and there was no appropriate Vessel Traffic Management System (VTMS) along the Kerala waters off the Arabian Sea. Sometimes heavy shipping traffic happened along the fishing grounds which encounter the fishing operations.

The deep-sea fishery could provide additional source of fish landings to ensuring the fish food and nutritional security in the state in the wake of numerous issues faced by coastal fisheries which includes over exploitation, juvenile fishing, discards, targeted fishery and conflicts among various resource users. As the deep-sea fishery resources could provide an alternative source of food and income for the masses, it is important to tap the underexploited deep-sea fishery resources.

Sustainable and economically viable resources exploitation from deep-sea fishery sector is still possible through appropriate regulatory management strategies with concerted policy efforts specific for different species and for different regions. In order to promote the deep-sea fishery in India, the government should provide adequate support and welfare measures to ensure that the cost of fishing operations tend to remain low and thereby increasing the net profits. The cost of fishing operation indicated that the fuel share is high restrained to the number of operations. Government should provide subsidies for the fuel to reduce the higher operating cost. Technological lag and financial constraints had been the major bottlenecks in the delayed take off of the deep-sea fishing industry in India. The strengthening of the existing Indian fleet is a prerequisite to further widening the exploitation of deep-sea resources. Redesigning the fleet in order to reduce its size and, at the same time, improving the efficiency of the remaining vessels in order to increase their economic fitness will improve the deep-sea fishing constraints for the future.

4.4 Conclusions

The study indicated that fuel is the most important and significant cost involved in the fishing operation, in addition to the huge capital investment required for the construction of the hull, engine, gears and other equipments. The profits in deep-sea shrimp trawling operation were found to be 24–25%. However discussions with the trawl owners indicated that high operation cost, high risk and efforts, lack of skilled and trained manpower, low market price realisation, abundance of discards, poor quality of shrimps, low level of harvesting technology were the major problems perceived to detrimental in the deep-sea shrimp fishing operations. There exits an increased risk and uncertainty in the deep-sea fishing operation necessitating free insurance coverage for deep-sea trawlers and implementation of vessel traffic management system. So in future, proper studies should be carried out and these issues should be considered prior to the execution of the programs for expansion of deep-sea fishery by government and other agencies. Further studies on the dynamics of this resources and associated fishery have to be encouraged for better management and sustainable use.

The government could consider providing adequate support and welfare measures in ensuring that the cost of fishing operation is reduced thereby consequently increasing the number of operations. The net profit can be enhanced by reducing the expenditure on fuel by introducing more fuel efficient fishing craft and gears. Considerable research and developmental initiatives is the need of the hour to ensure that deep-sea shrimp fishery operations become economically efficient as shrimp resources targeted and landed could provide supplementary fish sources for the fish food security in Kerala.

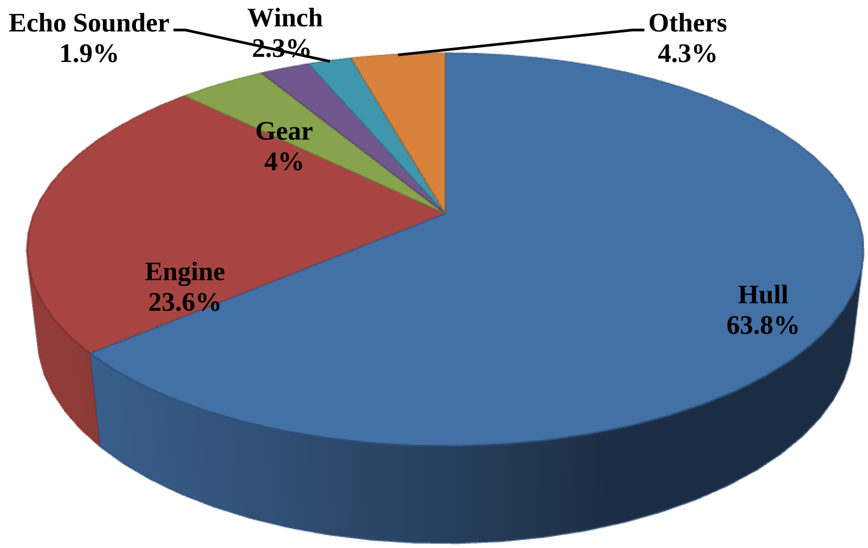


Figure 4.1. Average capital investments in deep-sea shrimp trawlers operated along Kerala coast

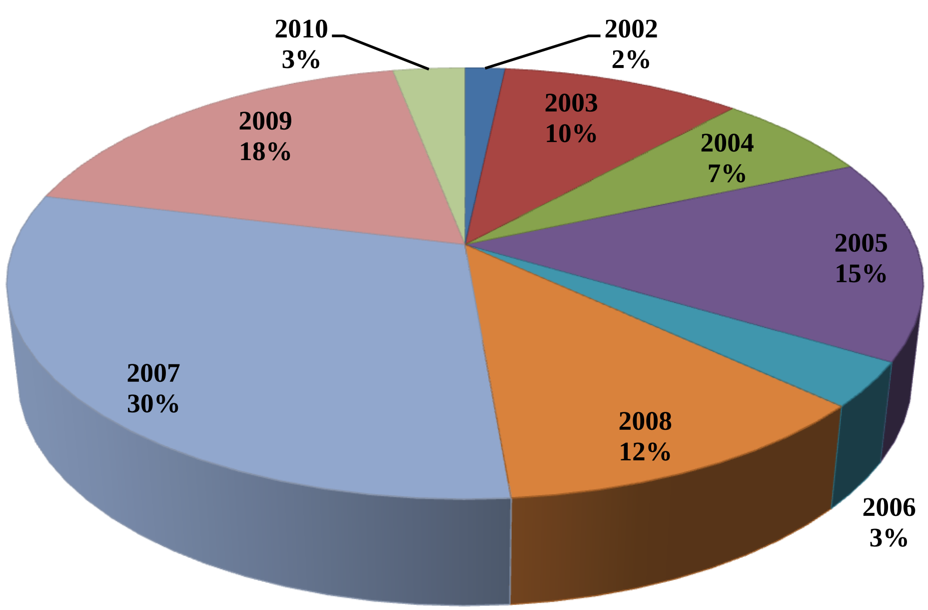


Figure 4.2. Year of purchase of deep-sea shrimp trawlers in Kerala

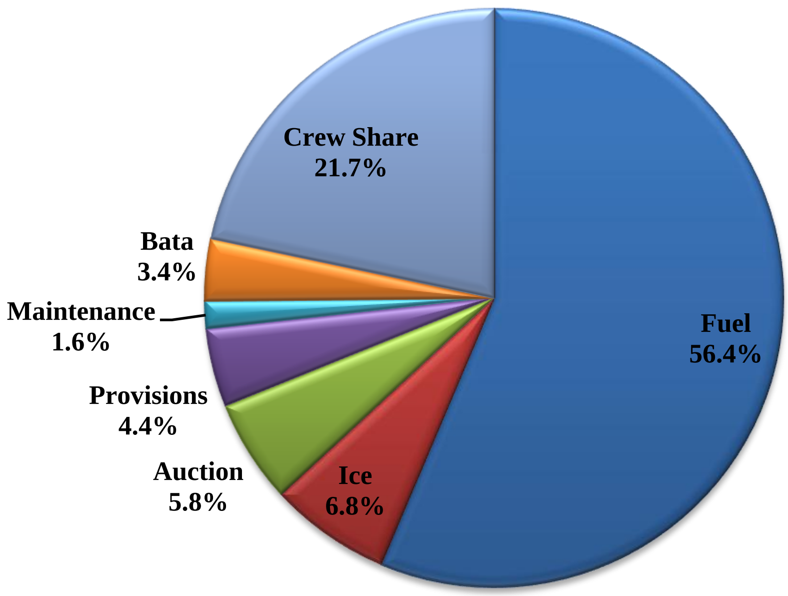


Figure 4.3. Average operational cost of trawlers targeted for ‘red ring’

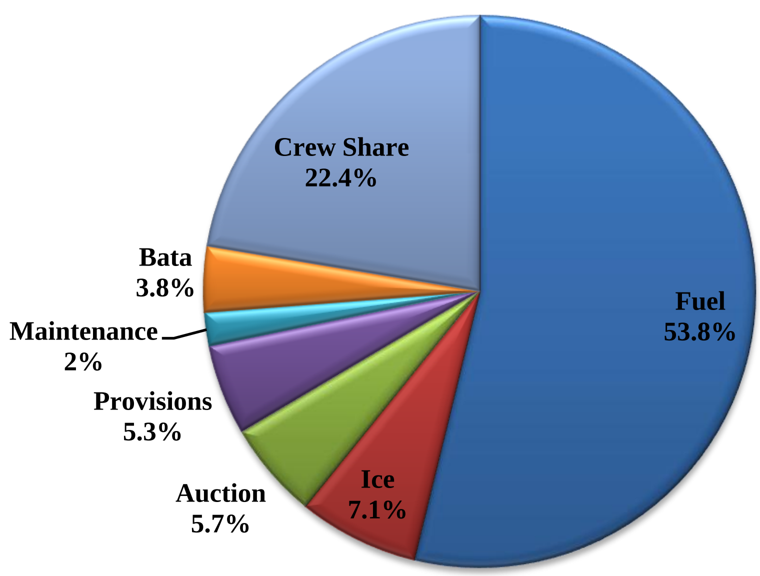


Figure 4.4. Average operational cost of trawlers targeted for other deep-sea shrimps

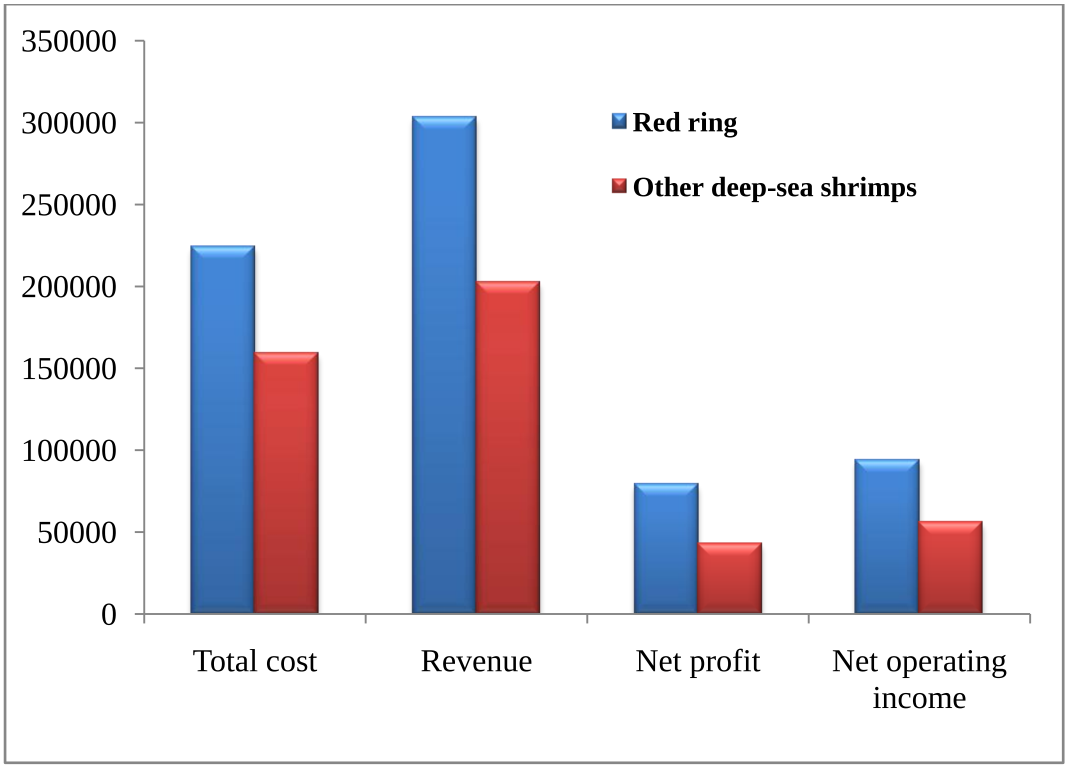


Figure 4.5. Cost and revenue of deep-sea shrimp trawlers

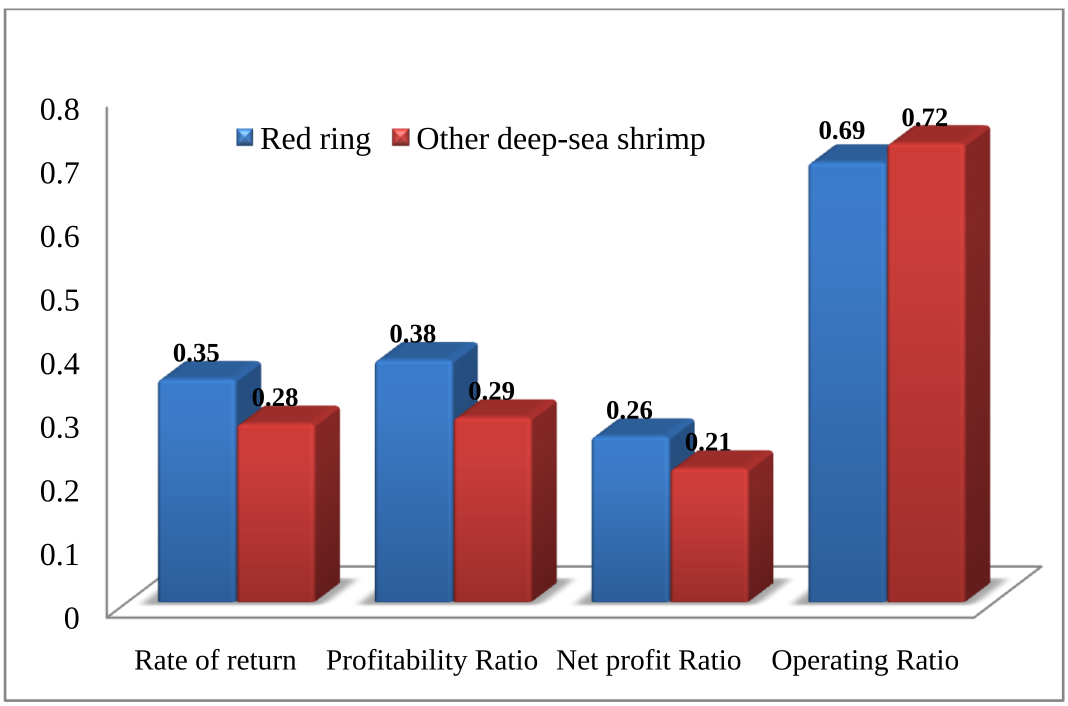


Figure 4.6. Economic efficiency indicators of deep-sea shrimp trawlers

Plate 4.1

Heap of deep-sea shrimp with by-catch finfishes

Sorting of deep-sea catch at Sakthikulangara Fisheries Harbour

Psenopsis spp. and *Neoepinnula* spp. landed as a by-catch in deep-sea shrimp trawler

Plate 4.2

By-catch landings of deep-sea shark *Echinorhinus* spp. at Kalamukk landing centre (Vypin)

By-catch of Chimaera, *Neoharriotta pinnata* at Sakthikulangara Fisheries Harbour

By-catch landings of deep-sea shark *Centrophorus* spp. at Cochin Fisheries Harbour

SECTION III

BIOLOGY AND STOCK ASSESSMENT OF *PLESIONIKA QUASIGRANDIS*

Chapter 5

Length-weight relationship and condition factor

5.1 Introduction

The knowledge of length-weight relationship has many applications in fishery biology, fish stock assessment and ecological studies. It establishes the mathematical relationship between two variables, length and weight (Beyer, 1987). The ratio of length to the weight is known to be a useful index to indicate the condition of fish. This expression had been used to find out an unknown variable from the known variable, to estimate the condition factor, to know the variation from the expected weight for various length groups to calculate the standing stock biomass when the length frequency distribution is known and to estimate yield per recruit in the analytical model of Beverton and Holt (Safran, 1992; Pauly, 1993; Petrakis and Stergiou, 1995). Length-weight relationship parameters are also useful for underwater visual census, with regard to conversion of length data into weight data and to find biomass estimates (Samoilys, 1997).

The proper relationship between length and weight varies among species according to their inherited body shape and within a species based on to the condition of individual organisms. Individual organisms within the same sample differ significantly and the average condition of each population varies seasonally (Sebastian, 2011). The length-weight relationships are considered as more appropriate for evaluating crustacean populations (Ivanovo and Krylov, 1980; Olmi and Bishop, 1983; Prasad *et al.*, 1989; Diaz *et al.*, 2001, Atar and Sector, 2003; Gorce *et al.*, 2006, Kapiris and Conides, 2009). Further, study of the length-weight parameters in aquatic organisms has broad application in demarcating the growth patterns during their developmental phases (Bagenal, 1978). Condition factor is used in fisheries in order to contrast the wellbeing of aquatic organisms. It is often used to quantify individual's physical wellbeing and is thought to be a useful complement in growth estimates of crustaceans (Rochet, 2000).

In shrimps, commonly used parameter for length weight relationship is either total length or carapace length. It is highly advantageous that the same dimension can be used by all those measuring shrimp from the same stock. In shrimps, carapace length is considerably more stable size reference dimension and this may contribute to its good correlation with body weight (Rhodesand Holdich, 1984). However most of the length-weight relationship studies on shrimps from Indian waters are based on the total length (Rao, 1988; Prasad, 2001; Radhika, 2004; Lalrinsanga *et al.,* 2012; Gopalakrishnan *et al.,* 2014). The use of carapace length to determine length-weight relationships has been widely applied for *Plesionika* species (Company and Sarda, 1997; Garcia *et al.,* 2000; Maiorano *et al.*, 2002; Chilari *et al.,* 2005; Cengiz *et al.* , 2012). Radhika (2004) reported total length-weight parameters and condition factor of seven deep-sea shrimps such as *Plesionika quasigrandis, P. martia. P. ensis, Heterocarpus gibbosus, H. woodmasoni, Aristeus alcocki, Solenocera hextii* and *Metapenaeopsis andamanensis* based on the sample collected from commercial landings and from exploratory surveys conducted off south west coast of India.

The present study describes total length-weight, carapace length-weight and total length-carapace length relationship and condition factor for male, ovigerous and non-ovigerous females of *P. quasigrandis.*

5.2 Materials and Methods

The samples were collected from Sakthikulangara, Vypine and Cochin Fisheries Harbour between January 2010 and December 2011. After removing the excess water on the shrimps by pressing with blotting paper, total length (TL) was measured using digital calipers with a precision of 0.01 mm as the distance from tip of rostrum to tip of telson and carapace length (CL) from the orbital margin to the posterior dorsal edge of the carapace. Weight (W) was measured using a digital balance with a precision of 0.01 g.

The relationship between total length-weight, carapace length-weight was estimated separately for the different groups; males, ovigerous females and non-ovigerous female, as well as for all the samples together by transforming the values of both variables to logarithamatic values and fitting a straight line by the method of least squares. The length-weight relationship can be expressed as

$W = a L^b$

Where, W = Weight of shrimp (g)

L = Total length / carapace length of shrimp (mm)

a= constant and equal the intercept of the straight line

b= exponent value coefficient of growth (slope).

The values of a and b was given a logarithm transformation according to the following formula:

$\log W = \log a + b \log L$

Based on this formula, constants ‘a’ and ‘b’ were calculated using least squares method. Linear relationship as $Y = a + bX$ suggested by Ivanov and Krylov (1980) was used for the carapace length- total length relationship.

Interaction between the variables was tested for significance to give the correlation coefficient. In order to test whether 'b' values obtained in the linear regressions were significantly different from the isometric value (3), by Student's t-test was done and expressed by the following equation (Zar, 1996).

$t = (b-3)/S_b$

Where, b = regression coefficient of log transformed data

S_b = standard error of b

Analysis of covariance (Snedecor and Cochran, 1967) was carried out to test for any significant difference in the relationship in the above parameters. The relative condition factor (Kn) was estimated for males, ovigerous females and non-ovigerous females.

Relative condition factor 'Kn' (Le Cren, 1951) is expressed as follows:

Kn =W/ ^W

Where, W= Actual weight in gram

^W= Calculated weight derived from total length-weight relationship

5.3 Results

5.3.1 Total length-weight relationship

Length-weight relationship of males, ovigerous females, non- ovigerous females and females are presented in Fig.5.1, Fig.5.2, Fig.5.3 and Fig.5.4 respectively. The total length in shrimps examined ranged from 65 to125 mm in males and from 62 to 132 mm in females. The length-weight relationship obtained from the samples is as follows

Male $W= 0.000001048 L^{3.286}$

Ovigerous females $W = 0.000000900419 L^{3.333}$

Non-ovigerous females= W= 0.0000010405 L $^{3.267}$

Combined (female) = W= 0.0000004755 L $^{3.464}$

Combined (sex) W= 0.000000635L $^{3.398}$

Table 5.1. Comparison of regression lines of the total length-weight relationship of *Plesionika quasigrandis* (male and female)

			Deviations from regression				
	df	b	df	SS	MS	F	Prob
Males	417	3.287	416	2.854	0.011		
Females	794	3.464	793	6.398	0.026		
Pooled	1211	3.384	1210	9.285	0.018		
Difference between slopes			1	0.033	0.033	1.801	0.180
Difference between adjusted mean			1	0.055	0.055	2.992	0.084

Table 5.2. Comparison of regression lines of the total length-weight relationship of *Plesionika quasigrandis* (ovigerous and non-ovigerous females)

			Deviations from regression				
	df	b	df	SS	MS	F	Prob
Non-ovigerous	305	3.267	304	2.959	0.028		
Ovigerous	489	3.334	488	3.906	0.027		
Pooled	794	3.307	793	6.867	0.027		
Difference between slopes			1	0.002	0.002	0.073	0.787
Difference between adjusted mean			1	1.262	1.262	45.404	1.12E-10

Logarithmic regression equations derived for males, ovigerous females, non-ovigerous females, female combined and combined sex using least square method are as follows:

Male Log W= -13.768 + 3.286 Log L (r^2= 0.878)

Ovigerous females Log W= -13.9204+3.333 Log L (r^2= 0.713)

Non-ovigerous females Log W= -13.7758+ 3.267 Log L (r^2= 0.796)

Combined (female) Log W= -14.5588 + 3.464 Log L (r^2=0.813)

Combined (sex) Log W= -14.2693 +3.398 Log L (r^2=0.814)

The exponential value for total length-weight relationship in males, ovigerous females, non-ovigerous females and females (3.286, 3.333, 3.267 and 3.464 respectively) indicate that there is a clear departure from the isometric growth pattern. Applying the t-test, it was shown that the regression coefficients of the three groups were significantly different from 3 at 1% level.

Analysis of covariance (ANACOVA) showed that there is no significant variation in the length-weight relationship between the two sexes and ovigerous females and non- ovigerous females (Table 5.1 and 5.2). Regressions obtained for different groups showed a lower correlation value for ovigerous females (0.713) than for non-ovigerous females (0.796) and males (0.878).

5.3.2 Carapace length-weight relationship

Carapace length varied from 12 to 25 mm in males and 11 to 27 mm in females. The carapace length-weight relationship of males, ovigerous females, non-ovigerous females and females are presented in Fig.5.5, Fig.5.6, Fig. 5.7 and Fig.5.8 respectively. The carapace length-weight relationship obtained from the samples is as follows.

Male   W= 0.000778 $L^{2.854}$

Ovigerous females W = 0.001511 $L^{2.623}$

Non-ovigerous females= W= 0.0006964 $L^{2.875}$

Combined (female) = W= 0.000882$L^{2.79893}$

Combined (sex) W= 0.000799$L^{2.837}$

Table 5.3. Comparison of regression lines of the carapace length-weight relationship of *Plesionika quasigrandis* (Male and female)

			Deviations from regression				
	df	b	df	SS	MS	F	Prob
Males	422	2.855	421	0.486	0.005		
Females	646	2.799	645	5.701	0.032		
Pooled	1068	2.820	1067	6.189	0.022		
Difference between slopes			1	0.001	0.001	0.070	0.790
Difference between adjusted mean			1	0.098	0.098	4.391	0.037

Table 5.4. Comparison of regression lines of the carapace length-weight relationship of *Plesionika quasigrandis* (ovigerous and non-ovigerous females)

			Deviations from regression				
	df	b	df	SS	MS	F	Prob
Non-ovigerous	262	2.875	261	3.878	0.036		
Ovigerous	381	2.623	380	1.758	0.026		
Pooled	643	2.782	642	5.655	0.032		
Difference between slopes			1	0.019	0.019	0.602	0.438
Difference between adjusted mean			1	0.046	0.046	1.434	0.232

Logarithmic equation for the relationship between carapace length and weight:

Male Log W= -7.1593+ 2.854 Log L (r^2=0.932)

Ovigerous females Log W= -6.49493209+ 2.623Log L (r^2= 0.755)

Non-ovigerous females Log W= -7.269452319+ 2.875Log L (r^2= 0.837)

Combined (female) Log W= -7.033310019+ 2.79893Log L (r^2=0.844)

Combined (sex) Log W= -7.131597014+2.837Log L (r^2=0.884)

The exponential value for carapace length-weight relationship were 2.854 for male, 2.623 for ovigerous females, 2.875 for non-ovigerous females and 2.837 for female (combined) and show that there is significant deviation from the isometric growth pattern. The‘t’ test confirmed ‘b’ significantly differs from 3, in all groups. Carapace length-weight relationships of selected *Plesionika* species from the various regions are presented in Table 5.5.

Analysis of covariance (ANACOVA) showed that there is no significant variation in the carapace length-weight relationship between the two sexes and ovigerous females, non-ovigerous females (Table 5.3 and 5.4). Regressions obtained for different groups showed a lower correlation value for ovigerous females (0.655) than for non-ovigerous females (0.737) and males (0. 0.932).

5.3.3 Total length-carapace length relationship

Relationships between total length and carapace length for males, females and combined sex are presented in Fig.5.9, Fig.5.10 and Fg.5.11 respectively. The equations for total length-carapace length relationship for males, females and combined sex are as follows:

Males: CL = -1.6005 + 0.9973 TL (r^2=0.809)

Females: CL= -2.05588 + 1.0959 TL (r^2=0.821)

Combined sexes: CL = -1.80555 + 1.04189 TL (r^2=0.823)

Table 5.5. Carapace length-weight parameters reported in selected *Plesionika* species (Company and Sarda, 1997; Gonzalez *et al.*, 1997; Garcia *et al.*, 2000; Maiorano *et al.*, 2002; Chilari *et al.*, 2005; Cengiz *et al.*, 2012)

Species	Sex	a	b	r	Area
P. acanthonotus	♂	0.0008	2.965	0.945	NW.Mediterranean
	♀	0.0026	2.550	0.928	
P. edwardsi	♂	0.0009	2.917	0.976	
	♀	0.0005	3.089	0.979	
P. edwardsi	♂	0.0012	2.805	0.976	W.Mediterranean
	♀	0.0009	2.943	0.977	
P. gigliolii	♂	0.0013	2.925	0.953	NW.Mediterranean
	♀	0.0024	2.601	0.888	
P. heterocarpus	♂	0.0006	3.088	0.990	
	♀	0.0007	2.987	0.981	
P. martia	♂	0.0010	2.840	0.950	
	♀	0.0008	2.890	0.970	
P. martia	♂	0.0010	2.840	0.950	Mediterranean Sea
	♀ Non-ovigerous	0.0008	2.890	0.970	
	♀ Ovigerous	0.0020	2.620	0.920	
	♀ Combined	0.0010	2.850	0.960	
P. martia	♂	0.0028	2.439	0.750	Ionian Sea
	♀ Non-ovigerous	0.0032	2.419	0.770	
	♀ Ovigerous	0.0023	2.496	0.560	
	♀ Combined	0.0032	2.419	0.700	
P. martia	♂	0.0086	2.171	0.708	E. Mediterranean
	♀ Non-ovigerous	0.0037	2.474	0.842	
P. narval	♀ Ovigerous	0.0071	2.257	0.642	Canary Island
	♂	0.0014	2.621	0.863	
	♀	0.0029	2.459	0.913	
P. quasigrandis	♂	0.0007	2.854	0.932	Arabian Sea
	♀ Non-ovigerous	0.0006	2.875	0.837	
	♀ Ovigerous	0.0015	2.623	0.755	
	♀ Combined	0.0008	2.798	0.844	

5.3.4 Relative condition factor (kn)

Results of the monthly relative condition factor (Kn) for the males, ovigerous females, non-ovigerous females and females for *P. quasigrandis* are given in the Table 5.6 and Fig.5.12. The mean monthly relative condition factor values varied from 1.005 to 1.112. The calculated mean Kn value for all groups was 1.059. The Kn values for the ovigerous females and non-ovigerous females varied from 0.881 to 1.295 and from 0.965 to 1.354 respectively.

Minimum Kn value was observed in March for ovigerous females and February for non-ovigerous females. Maximum Kn value was observed in November for both ovigerous and non-ovigerous females. In respect of the males Kn values varied from 0.901 to 1.088. Minimum and maximum values were obtained in April and September respectively.

Table 5.6. Monthly relative condition factor (Kn) of *Plesionika quasigrandis* during the period 2010–2011

Months	Male	Ovigerous females	Non-ovigerous females	Female combined
January	0.994	1.139	1.003	1.126
February	0.983	0.94	0.965	0.913
March	0.961	0.881	1.025	0.902
April	0.901	0.942	0.911	0.974
May	0.943	0.926	1.084	0.974
August	1.086	1.042	0.963	1.022
September	1.088	1.122	1.09	1.048
October	1.086	1.149	1.009	1.198
November	1.011	1.295	1.354	1.139
December	1.006	1.179	1.026	1.224

5.4 Discussion

A characteristic of the length-weight relationship in fishes and decapods is that the value of the exponent b around 3 is considered ideal for individuals which maintain a constant body shape. However, in many cases the cube law is apparently not obeyed as the organisms change their shape during growth. If b value is different from 3, growth is said to be allometric. Allometric growth may be negative ($b<3$) or positive ($b>3$). Thus, some indication of the condition of organisms in a population can be obtained from the length-weight equation. The value of exponent for males, ovigerous females and non-ovigerous females of *P.quasigrandis* in the carapace length-weight relationship in the present study were below 3 indicating decreasing growth rate in relation to length. Weight of most of the crustaceans is close to the cube of the length (Jayachandran and Joseph, 1988). Pattern of weight increment varied among different groups in the present study which are in agreement with those obtained for *P. martia* collected from the Mediterranean Sea (Maiorano *et al.,* 2002; Chilari *et al.*,2005; Cengiz *et al* ., 2012). Negative allometry was observed in both sexes of deep-sea shrimps *P. acanthonotus* and *P. gigliolii* (Company and Sarda, 1997) and *P. edwardsi* (Garcia *et al.,* 2000). Radhika (2004) also reported negative allometric growth in female *P. martia* from Arabian Sea. However, Company and Sarda (1997) reported the b value close to 3 in both sex of *P. heterocarpus* and *P. edwardsii* in the Mediterranean Sea. Similar negative allometry was also observed in the deep-sea shrimp species of the family Aristidae (Ragonese *et al.*, 1997; Carbonell *et al.*, 1999).

The exponential value is lower in ovigerous females of *P.quasigrandis* compared to non-ovigerous in the present study and is the conformity with the same reported in *P. martia* from Mediterranean Sea (Maiorano *et al*., 2002; Cengiz *et al.*, 2012). Body weight increases fast beyond size at first maturity and was visibly more rapid in adult females compared to adult males. This is due to the development of ovaries in mature females and to presence of eggs on the abdomen of berried females.

The calculated exponential value of *P.quasigrandis* in different groups (male, ovigerous and non-ovigerous females) based on total length-weight relationship is above 3. However, Radhika (2004) reported negative allometry in both sexes of the same species, but the study has not included length-weight parameters separately for berried females. The relationship showed positive allometry in the case of deep-sea pandalid shrimps *H. gibbossus* and *H. woodmasonii* (Radhika, 2004), which lives in deeper environment in the same geographical area. The exponential values in deep-sea decapods were correlated to the life habits of the species and the highest exponential values were observed for strictly benthic species and the lowest for mesopelagic species (Company and Sarda, 2000). The regression coefficient (r^2) gives an idea about the correlation between length and weight. If it is around 1, it means that length and weight are perfectly correlated. In the present study, correlation coefficients differ from 0.713 to 0.932.

Condition factor is an index reflecting interactions between biotic and abiotic factors in the physiological condition of organisms (Sebastian, 2011). Condition factor is a useful index for monitoring of feeding intensity and reproductive condition of individuals (Oni *et al*., 1983). The Kn value observed in *P. quasigrandis* ranges from 1.005 to 1.112 indicating that the shrimps are in good condition. The mean Kn obtained in this study varied slightly from studies conducted by Radhika (2004) in the same species with highest Kn values for males in January and March and for females in November. However, in the present study highest Kn value were observed for both sexes in September.

The mean Kn value was higher in ovigerous females (1.061) than those from non-ovigerous females (1.043) and males (1.005). The most significant factor that influences the condition factor of organisms is its reproductive activities (Lizama and

Ambrosio, 2002). Significantly higher Kn value in ovigerous females compared to non-ovigerous females in the present study may be attributed to the presence of eggs. The gradual increase in Kn from October to January with lowest value in March coincided with the peak spawning season.

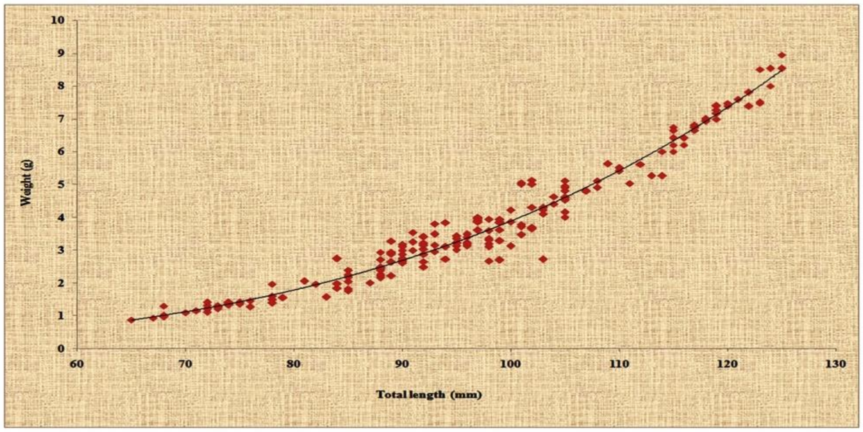


Figure 5.1. Relationship between total length and weight in males of *Plesionika quasigrandis*

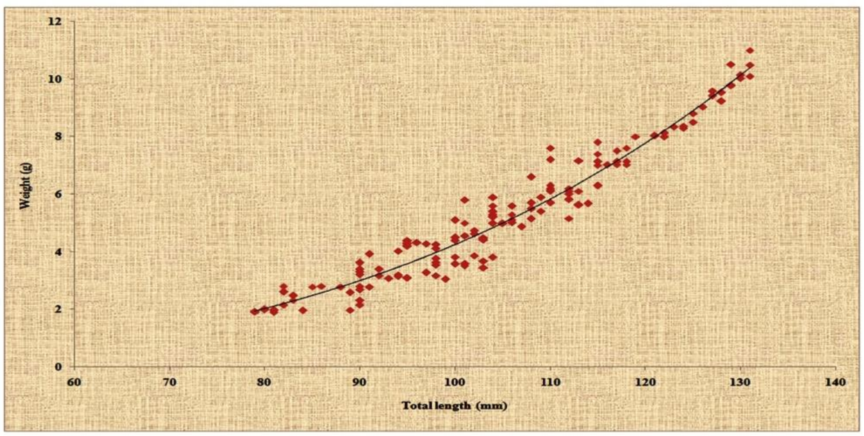


Figure 5.2. Relationship between total length and weight in ovigerous females of *Plesionika quasigrandis*

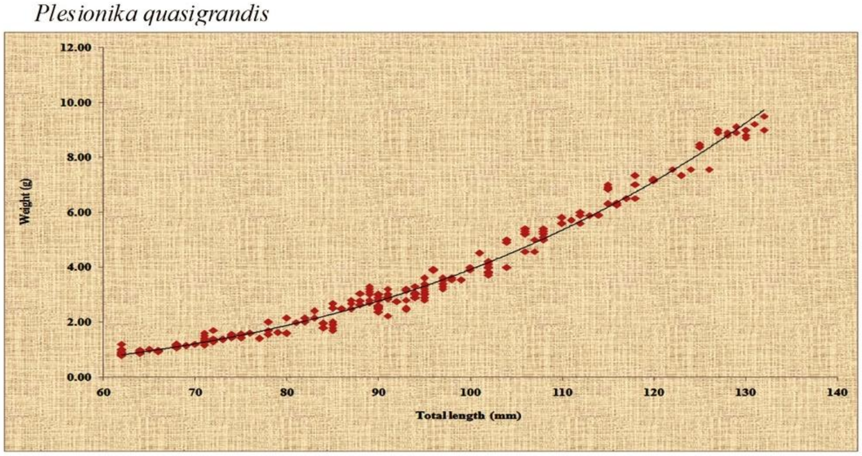


Figure 5.3. Relationship between total length and weight in non-ovigerous females of *Plesionika quasigrandis*.

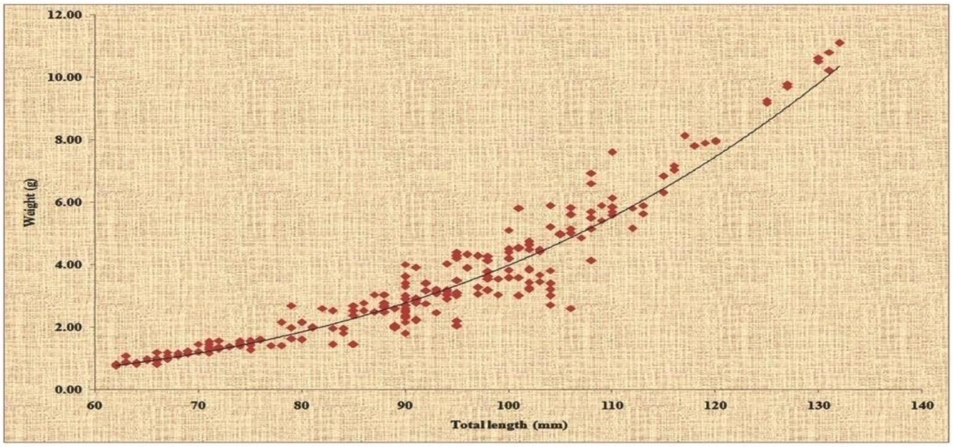


Figure 5.4. Relationship between total length and weight in females of *Plesionika quasigrandis*.

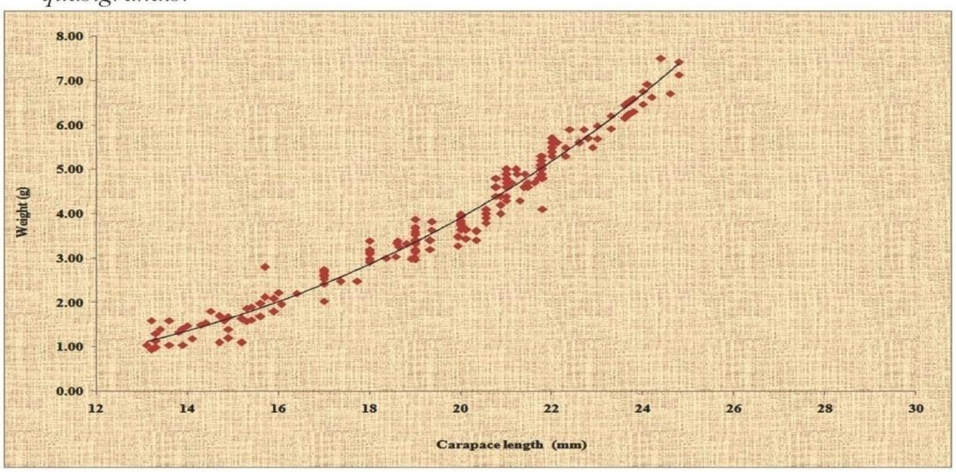


Figure 5.5. Relationship between carapace length and weight in males of *Plesionika quasigrandis*.

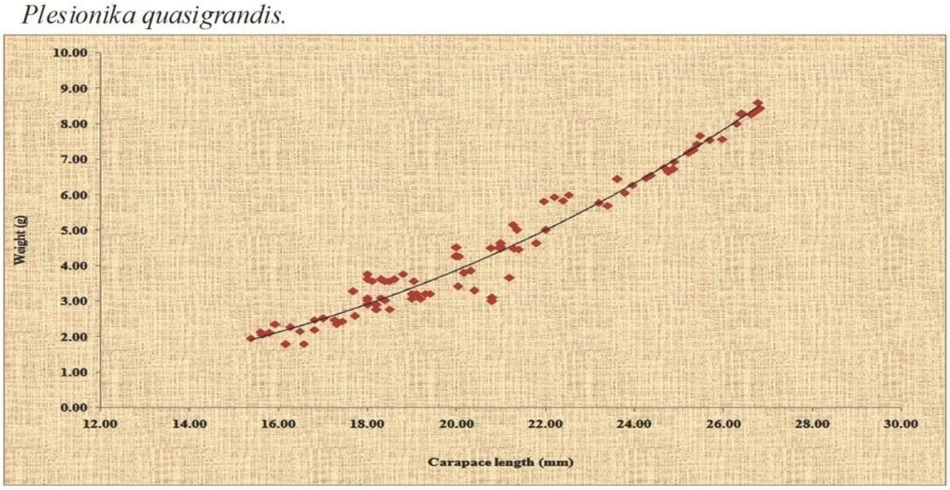


Figure 5.6. Scatter diagram of relationship between carapace length and weight of ovigerous females *Plesionika quasigrandis*.

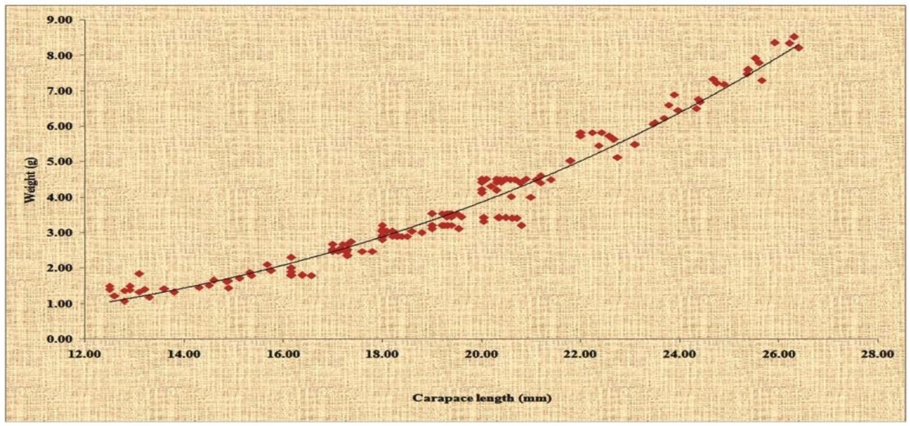


Figure 5.7. Relationship between carapace length and weight in non- ovigerous females of *Plesionika quasigrandis*.

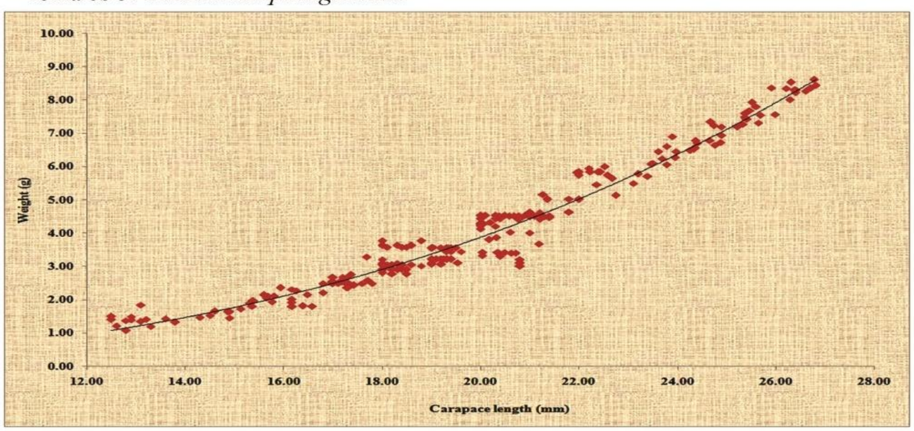


Figure 5.8. Relationship between carapace length and weight in females of *Plesionika quasigrandis.*

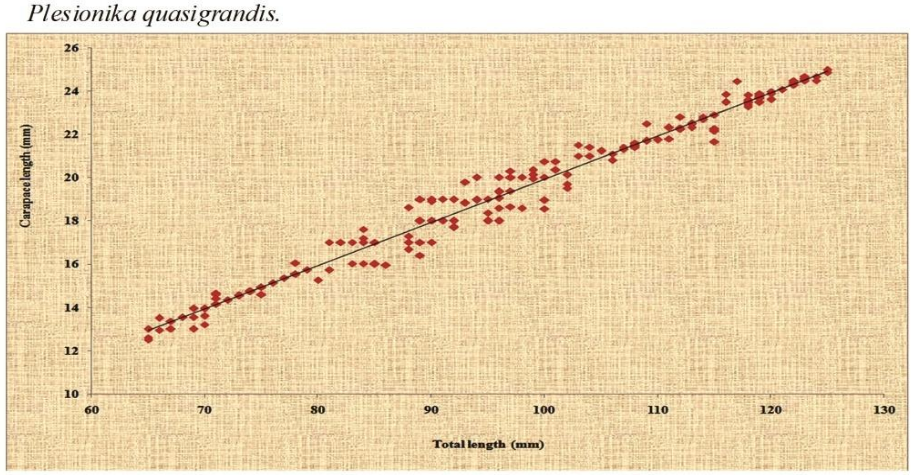


Figure 5.9. Total length - carapace length relationship in males of *Plesionika quasigrandis*

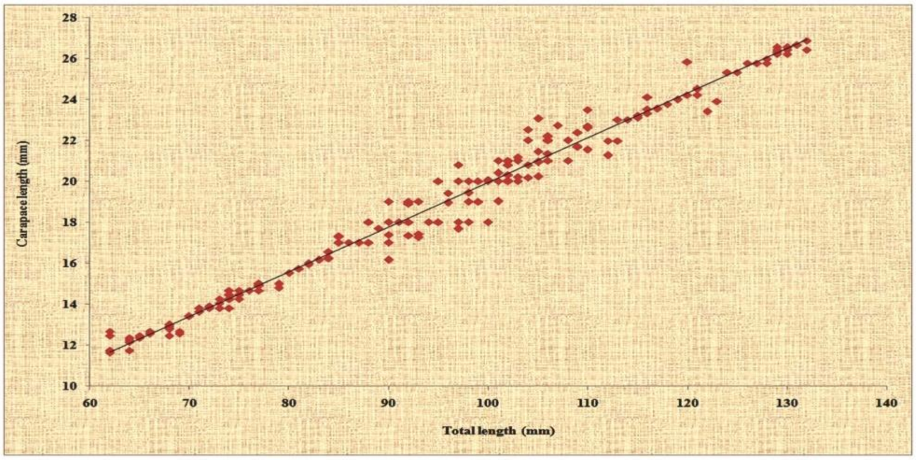


Figure 5.10. Total length - carapace length relationship in females of *Plesionika quasigrandis*

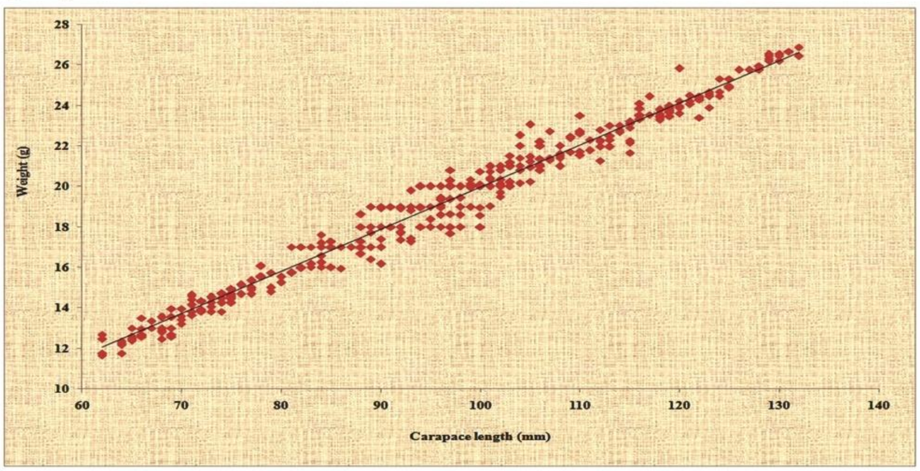


Figure 5.11. Total length - carapace length relationship in pooled sex of *Plesionika quasigrandis*

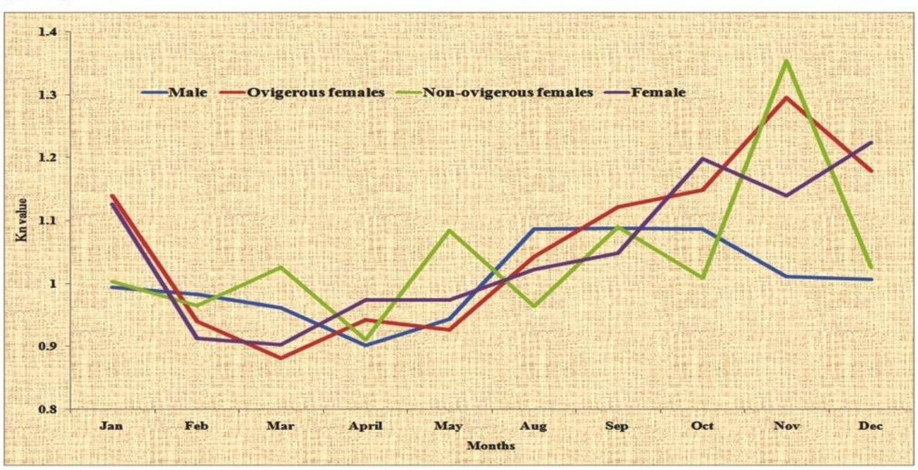


Figure 5.12. Month wise relative condition factor of *Plesionika quasigrandis*

Chapter 6

Reproduction

6.1 Introduction

Reproduction is an important aspect in the life history of a species. Knowledge on reproductive cycle is significant for the study of the biological investigation of a species and information on reproductive aspects in relation to fishery practices is vital to achieve the sustainable management of the fishery. Reproductive pattern of a species is directly related to a species life strategy (Oh and Hartnoll, 2004). The reproductive cycle of marine invertebrates may be continuous or seasonal (Giese and Pearse, 1974). In general, most of the coastal species shows seasonal reproductive cycle. Orton (1920) opined that deep-sea is a physically seasonless environment and breeding period of deep-sea species ought to be continuous throughout the year.

Breeding patterns in crustaceans are a result of both environmental conditions and exchange between growth and reproductive processes (Anger, 2001). Water temperature, water depth and availability of larval food, which might influence the reproductive period of marine benthic invertebrates (Ahamed and Ohtomi, 2011). According to Company and Sarda (1997) light, pressure, temperature, food availability and predator density are some of the aspects which influence species distribution and lifecycles.

Important reproductive aspects related to the fishery include sex ratio, fecundity, developmental stages, size at first maturity, breeding season. The studies on the maturity and size at first maturity are helpful in evaluating the potential stock recruited to the population. Length at sexual maturity of a species differs from one habitat to another and this may be due to the varied climatic and trophic parameters that characterize different areas (Sinovcic and Zorica, 2006). Studies on maturity are mostly targeted at female individuals. Sex ratio studies are useful in understanding whether any privileged fishing exists, its possible bearing on the fishery and whether sexual congregation takes place during spawning. Knowledge of fecundity is important to measures the abundance and reproductive potential of the spawning stock. Egg size is one of the most significant and regularly studied aspects of the life history of marine organisms, and much interest has focused on the ecological factors that drive changes in egg size (Strathmann, 1985; Lessios, 1990; Levitan, 2006). Sex reversal was reported in *Pandalus danae, P. jordani* and *P. borealis* (Berkeley, 1929; Butler, 1964) and there is no report on *Plesionika* species. King and Mofitt (1984) observed that *Plesionika* and *Heterocarpus* genus in the pandalidae family are dioecious. Even though annual reproduction has been reported in some deep-sea animals, majority of deep-sea species showed continuous reproduction throughout the year (Tyler, 1986, 1988; Harrison, 1988; Gage and Tyler, 1991; Bishop and Shalla, 1994).

Various studies conducted on the reproductive aspects of pandalid shrimps showed that temperature of the water is one of the significant factors affecting on spawning (Allen, 1966; Bauer, 1989). Bergstrom (2000) observed that the breeding period of many *Pandalus* species varies considerably with ambient temperature. Omori (1974) observed that the larger eggs size, low fecundity and continuous reproduction are the general pattern of deep-sea decapods. Studies on the reproductive biology of *Plesionika* species were mainly from Mediterranean Sea.

Significant studies on the reproductive traits of *Plesionika* species are on *P.acanthonotus, P. edwardsii, P. gigliolii, P. heterocarpus* and *P. martia* from northwestern Mediterranean Sea and eastern central Mediterranean Sea (Company and Sarda,1997; Colloca, 2002; Maiorano *et al.,* 2002), *P. izumiae* from Japanese waters (Omori, 1971; Ahamed and Ohtomi, 2011), *P. semilaevis* from Kagoshima Bay (Ohtomi, 1997), *P. martia* from Eastern Ionian Sea (Chilari *et al.,* 2005) and *P. edwardsii* from northern Tyrrhenian Sea (Possenti *et al.,* 2007).

Detailed studies on reproductive aspects in relation to the fishery of deep-sea shrimps in India restricted to two species, *Heterocarpus gibbosus* and *H.woodmasoni* (Radhika, 2004). Rao and Suseelan (1967) and Menon (1972) conducted preliminary studies on the larval stages of *Heterocarpus* species collected from the deep-sea exploratory surveys. Mohamed and Suseelan (1973), Suseelan (1974) and Suseelan *et al.* (1989) carried out investigations on sex ratio, fecundity and egg size of the deep-sea shrimp species in the genus *Plesionika* and *Heterocarpus* collected from the exploratory surveys off South West coast of India. Rajan *et al.* (2001) and Thirumilu and Rajan (2003) had made preliminary attempts to elucidate the reproductive pattern of some deep-sea shrimps landed in the commercial catches. However, detailed information on the reproductive aspects of *P. quasigrandis* is totally lacking from Indian waters. This study aimed to investigate general aspects of reproductive biology in relation to fishery such as sex ratio, spawning period, size at first maturity, fecundity, egg size, reproductive load and reproductive output of *P. quasigrandis.*

6.2 Materials and methods

Samples were collected from Sakthikulangara, Vypin, Cochin Fisheries

Harbour during January 2010 to December 2011. Sex was determined by observing the shape of the endopod in the first pair of pleopods and based on the presence or absence of the masculine appendix in the second pair of pleopods (King and Moffitt, 1984). The ovigerous or non-ovigerous state of females was also recorded. Three stages of gonadal and egg development were assigned, according to Company and Sarda (1997). Size at the onset of sexual maturity (SOM) is considered as the size of the smallest males with masculine appendix and the size of smallest ovigerous females are estimated. For females, the mean size at first maturity (the size at which 50% of the female population was ovigerous) has also estimated as suggested by King and Butler (1985).

The month wise and length group wise sex ratio was estimated. Samples are grouped into 5 mm class intervals for length group wise sex ratio analysis. The result was tested by Chi-square analysis (Snedecor and Cochran, 1967) for differences from the hypothetical ratio of 1:1, if any. The chi-square formula used on these data is

$$\chi^2 = \frac{(O - E)^2}{E}$$

Where, χ^2 = Chi Square

O = Observed frequency

E= Expected frequency

Total length (TL) was measured using digital caliper with a precision of 0.01 mm as the distance from tip of rostrum to tip of telson and carapace length (CL) from the orbital margin to the posterior dorsal edge of the carapace. Body weight (W) was measured using a digital balance with a precision of 0.01 g.

Relative monthly frequency of ovigerous females was analyzed for the definition of the reproductive period. The egg size was measured to the nearest 0.01 mm for each stage of egg development using Motic stereomicroscope with image analyzer. Fecundity was estimated from the number of eggs from ovigerous females (Stage1) of different sizes. In caridean shrimps, fecundity was estimated as the number of eggs laid per spawning that can be found attached on the female's pleopods. Eggs carried on the pleopods were gently detached with fine forceps and any setal material or extraneous matter was removed. Total weight of eggs in the brood pouch was recorded and a sample is taken out and weighed to the nearest 0.001 gm, using an electronic balance. Number of eggs in the sample was counted. Total number of eggs was calculated by the equation:

$$\text{Fecundity}=\frac{\text{Number of eggs in the sample } \times \text{Total weight of the eggs}}{\text{Weight of the sample}}$$

To establish a relationship of fecundity 'F' with total length and total weight following formula (Bagenal, 1978) was used

Fecundity= a X^{b}

Where, X = Total length/ Total weight, a= constant, b= exponent

Females with eggs in the early developmental stages (stage I) was used for the estimation of fecundity and reproductive output for avoiding potential egg loss, as suggested by Balasundaram and Pandian (1982), Kuris (1991) and Anger and Moreira (1998).

Reproductive output (RO) was calculated for ovigerous females with early egg development stage (Stage I) following formula (Clarke *et al.*, 1987).

$$\text{Reproductive output}=\frac{\text{Total weight of eggs}}{\text{Body weight of females without eggs}}$$

Reproductive load was calculated using the following formula given by Cushing (1981)

$$\text{Reproductive load}=\frac{\text{Lenght at first maturity}}{\text{Asymptotic length}}$$

6.3 Results

6.3.1 Sexual dimorphism

Two external morphological characters are mainly used for the sex determination. Sex of Individual shrimps was determined by the examination of the shape of the endopod of the first pleopods (Fig.6.1. A and B) and based on the presence or absence of masculine appendix on the endopod of the second pleopod. The masculine appendix (Fig.6.2) is a spinous process closest to the appendix interna on the endopod of the second pleopods. An appendix interna is present on each of the 2^{nd} to 5^{th} pleopode of both sexes. The masculine appendix is found only in adult and sub adult males and this appendix is small or absent in juveniles.

6.3.2 Sex ratio

Overall sex ratio during 2010–2011was 1:1.4 in favors of females which was significantly different from the expected sex ratio. Females outnumbered males throughout the year in the present study period and sex ratio significantly varied from the expected sex ratio ($P <0.05$) during April, May, October, November and December. High percentage of females were observed in May (66.8%) followed by December (66.1%). Monthly variations in sex ratio and results of chi-square value are provided in Table 6.1.

Length wise sex ratio (M:F) of population of *P. quasigrandis* is given in the

Table 6.2. Dominance of females was observed in all length groups, except 76-80 mm length class. Males were absent in the higher length class such as 126-130 mm and 131-135 mm. Chi-square analysis, carried out to understand the significance of the ratio, showed that there is no significant variation in the ratio of male and female up to 121-125 mm length group.

Table 6.1. Monthly sex ratio of *Plesionika quasigrandis* during 2010–2011

Months	Male%	Female%	Sex ratio (M:F)	Chi-square value (X^2)
January	54.8	45.2	01:0.81	2.98
February	49.7	50.3	01:01.0	0.01
March	44.1	55.9	01:01.3	3.18
April	38.6	61.4	01:01.6	11.66*
May	33.2	66.8	01:02.0	36.56*
August	48.7	51.3	01:01.0	0.21
September	49.2	50.8	01:01.0	0.12
October	42.1	57.9	01:01.4	7.44*
November	33.9	66.1	01:01.9	39.83*
December	38.9	61.1	01:01.6	12.44*

*Significant at 5% level

6.3.3 Egg developmental stages

In pandalid shrimps fertilization is external and occurs during the spawning of oocytes when they pass through the spermatophores, stored inside the females prior to copulation. The fertilized oocytes are glued to the pleopods of the female until hatching. Three stages of egg developmental stages were identified according to morphological examination, size and colour (Fig.6.3, Fig.6.4 and 6.6).

Stage I (Early Stage): Eggs of recent spawning with intense colour. Eggs are dark green-blue colour without eye pigmentation. Size of egg ranged between 0.43 and 0.64 mm.

Stage II (Middle Stage): Eggs are pale green blue colour and embryo eye pigmentation not clearly visible. Egg size ranged between 0.61and 0.77 mm.

Stage III (Late stage): Colourless eggs with embryo eye pigmentation well visible and embryo well developed. Egg size ranged between 0.72 and 0.91 mm.

Table 6.2. Length wise sex ratio of *Plesionika quasigrandis* during 2010–2011

Length class (mm)	Male %	Female%	Sex ratio	Chi-square value (X^2)
61-65	43.48	56.52	01:01.3	0.4
66-70	45.95	54.05	01:01.2	0.2
71-75	49.23	50.77	01:01.0	0
76-80	51.89	48.11	01:00.9	0.3
81-85	49.79	50.21	01:01.0	0
86-90	49.73	50.27	01:01.0	0
91-95	49.45	50.55	01:01.0	0.1
96-100	49	51	01:01.0	0.2
101-105	49.63	50.37	01:01.0	0
106-110	49.75	50.25	01:01.0	0
111-115	49.44	50.56	01:01.0	0
116-120	49.37	50.63	01:01.0	0
121-125	46.94	53.06	01:01.1	0.2
126-130	-	100	-	11*
131-135	-	100	-	7*

*Significant at 5% level

6.3.4 Length at first maturity

Total length of ovigerous females ranged from 79 to 131 mm. The mean length at first maturity for females was estimated as 84 mm (Fig.6.11). The longevity of female *P.quasigrandis* was estimated as 5.7 years and the females attain the sexual maturity in 1.5 years. Size at the onset of sexual maturity (the smallest males with masculine appendix and the size of smallest ovigerous females) for male was 77 mm and female was 79 mm.

6.3.5 Fecundity

Fecundity was estimated by direct counting eggs found on the pleopods of berried females. Number of eggs present in the berried females (Stage I) of shrimp in the length range between 89 mm and 128 mm has been estimated in the present study. The overall fecundity varied from 1461 eggs (TL =89 mm, TW = 2.55 g) to 7189 eggs (TL =128 mm, TW= 8.96 g) with an average of 5196 eggs. Scatter diagrams of fecundity against total length and total weight were plotted in the Fig. 6.7 and Fig. 6.8.

The relationship of fecundity to the total length and weight observed during the present study are as follows:

$F = 0.00091\ TL^{3.29}$ ($r^2 = 0.673$)

$F = 836\ TW^{1.05}$ ($r^2 = 0.807$)

There was strong correlation between total length, total weight and the number of eggs. Fecundity increases with increase in length and weight. The absolute fecundity values differ in shrimp from species to species and individual of the same species shows varying number of eggs depending on their length. Fecundity and egg size of selected *Plesionika* species are summarized in Table 6.3.

6.3.6 Reproductive output and reproductive load

The reproductive output (RO) varied between 0.07–0.13 and the egg weight comprised an average of 9.9% of the body weight of female in early developmental stage. The RO of *P.quasigrandis* was higher in small age groups than in older groups. There was no statistically significant correlation between reproductive output and total length in shrimp, showing that reproductive output is not determined by size of individuals. The calculated value for the reproductive load of *P.quasigrandis* was 0.58 in females.

Table 6.3. Fecundity and egg size reported in selected *Plesionika* species (Omori,1971; Suseelan,1974; Company and Sarda, 1997; Ohtomi,1997; Maiorano *et al.*, 2002, Chilari *et al.*, 2005; Ahamed and ohtomi, 2011)

Species	Carapace length (mm)	Fecundity	Egg size (mm)	Location
P. acanthonotus	9.6-17.9	3156	0.48-0.53	W. Mediterranean sea
P. edwardsii	21.0-25.0	920-19792	-	Northern Tyrrhenian Sea
P. ensis	-	2625	0.64-0.90	Arabian Sea
P. gigliolii	9.3-18.6	4294	0.48-0.55	W. Mediterranean Sea
P. heterocarpus	11.0-20.2	5851	0.44-0.53	W. Mediterranean Sea
P. izumiae	5.2-8.0	184-1086	-	Suruga Bay
P. izumiae	7.4-14.7	479-4405	0.51-0.68	Kagoshima Bay
P. martia	14.2-26.7	4105	0.45-0.55	W. Mediterranean Sea
P. martia	8.1 -26.2	2966	0.39-0.79	EC Mediterranean Sea
P. martia	11.8-22.9	618-6244	-	Eastern Ionian Sea
P. martia	-	2733	0.50-0.75	Arabian Sea
P.narval	7.9-18.7	200-7500	-	Aegean Sea
P.quasigrandis	17.4-26	5196	0.43-0.91	Arabian Sea
P.quasigrandis	-	3972	0.75-0.96	Arabian Sea
P. semilaevis	10.4-18.0	1048-8702	-	Kagoshima Bay

6.3.7 Spawning season

Percentage of ovigerous females in landings was used to find out the reproductive period of *P. quasigrandis* from Kerala coast. Presence of ovigerous shrimps was observed in the landings throughout the year, however, their proportion varied monthly. Annual reproductive cycle of shrimp in this study was almost similar during the two years. Main breeding season was during October to January as evidenced by the higher proportion of ovigerous female. High percentage of ovigerous females observe during November in 2010 (73.4%) and December in 2011 (71.6%). Overall percentage of berried females was 63.47% during 2010 and 61.16% during 2011. Percentage of ovigerous females in each of the egg developmental stages is shown in Fig. 6.9 and Fig.6.10. Percentage of ovigerous female with Stage III observed very low in the landings of all months.

Table 6.4. Monthly percentages of ovigerous females during 2010-11

Months	2010	2011
January	71.3	65.7
February	61.8	63.5
March	61.8	62.3
April	58.7	47.1
May	51.2	53.2
August	54.6	60.4
September	66.9	57.9
October	64.4	63.1
November	73.4	66.8
December	70.6	71.6

*No deep-sea trawling operations during June and July

6.4 Discussion

Information on the reproductive biology of a species is one of the most significant aspects in evaluating the harvesting strategies of exploited populations. In shallow water pandalid shrimp, most of the species are protandrous hermaphrodites. In protandry individuals function as males early in life then change sex and reproduce as females for the rest of their life (Bergstrom, 2000). King and Moffitt (1984) and Company and Sarda (1997) presented evidence that most of the species of deep-sea tropical pandalids are dioecious. Even though sex reversal was reported in many pandalid shrimps, especially in the *Pandalus* genus (Berkeley, 1930; Butler, 1964; Hayashi 1988; Bergstrom, 2000) there were no reports on sex reversal in the *Plesionika* species. Completely developed masculine appendix was observed in male above 77 mm and they were therefore considered as adults.

Hypothetically, expected composition of males to females is 1:1 (Holcik *et al.,* 1988). In the present study it is noted that in *P.quasigrandis,* females dominated in the fishery throughout the year and the chi-square value showed that the yearly distribution of males and females was significantly different from 1:1 ratio. The study conducted by Radhika (2004) and Rajan *et al.* (2001) observed the dominance of female population of *P. quasigrandis* from Kerala coast. Suseelan *et al.* (1974) also reported the dominance of females in the *P. quasigrandis* population off south west coast of India based on deep-sea exploratory survey. But Radhika (2004) observed dominance of males of *P. quasigrandis* in higher length groups which is divergence with the present study. Dominance of females in the population of pandalid shrimps is reported in many other species. Predominance of females in the population of *P. edwardsii* was reported from the Spanish western Mediterranean (Garcia *et al.,* 2000) and the northern Tyrrhenian Sea (Possent *et al.,* 2007). Less numbers of male population was also reported among *P. martia* from the Sardinian waters (Campisi *et al.,* 1998), from the eastern-central Mediterranean Sea (Maiorano *et al.,* 2002), from Albanian waters of the southern Adriatic Sea (Marsan *et al.,* 2000) and from western Mediterranean Sea (Carbonell *et al.,* 1998). Sex ratio in the population may be connected with longevity of shrimp species. Longevity of females was higher than males in *P. quasigrandis* (chapter 8). Difference in sex ratio may also be explained as differential mortality or distribution pattern between sexes.

Egg size is one of the most significant aspect in the life history of free spawning marine animals and is related with larval developmental type and many lifecycle characters (Moran and Justine, 2009). Egg size of shrimp increased during incubation, which is a general pattern in decapods (Wear, 1974; Pandian, 1994). This was mainly because of the increased water content and variation in the biochemical composition during embryonic progress (Subramonian, 1991; Clarke, 1993). Mean egg size of *P.quasigrandis* shows higher values compared to other species of the genus *Plesionika*, such as *P. acanthonotus, P. gigliolii, P. martia, P. heterocarpus* and *P. edwardsii* (Company and Sarda, 1997; Maiorano *et al.*, 2002). Many investigations established that large eggs have more yolk (Guerao and Ribera, 2000; Oh and Hartnoll, 2004). Comparison between egg size at early and late development stages visibly confirmed a considerable increase in size during incubation.

Size at sexual maturity is of special significance in fisheries management and is broadly used as an indicator for smallest allowable capture size (Lucifora *et al.,* 1999). Percentage of ovigerous females increased with growth and attained 50% at a total length of 84 mm, suggesting the length at sexual maturity of *P. quasigrandis*. Size at sexual maturity varies from one habitat to another and this might be due to the diverse climatic and trophic parameters that characterize various areas (Sinovcic and Zorica, 2006). Females of shrimp attain the size at first sexual maturity in their 1.5 years. Maiorano *et al.* (2002) reported length at first sexual maturity in the second year of *P.martia* from Mediterranean Sea.

Linear relationship between fecundity and body weight shows that number of eggs increases almost in direct proportion to body weight. Number of eggs increases with the body length of the species, a rule that seems more applicable to crustaceans than to fish (Sastry, 1983). Fecundity of shrimp was directly proportional to length of the animal in the present study and the same was reported by other authors in many shrimp species (Radhika, 2004; Dineeshbabu 2005; Possenti *et al.,* 2007). In caridean shrimps, the number of eggs per brood is strongly related with female body size (Berglund, 1981). According to Masshiko (1990) number of eggs also varies in relation to hydrographic region.

Average fecundity was high in *P.quasigrandis* when compared to *P. acanthonotus, P. gigliolii, P. martia* and *P. semilaevis* (Company and Sarda, 1997; Maiorano *et al.,* 2002; Chilari *et al.,* 2005; Ahamed and Ohtomi, 2011) and less when compared to *P. heterocarpus* and *P. edwardsii* (Company and Sarda, 1997; Possenti *et al.*, 2007). High fecundity of this species observed in the present study, when compared to other *Plesionika* species with same size range may be due to selection of females carrying eggs at early developmental stage (stage I) for fecundity estimation. Possent *et al.* (2007) opined that high variation in the fecundity of *Plesionika* species may be due to the variability in size and the habitat of the different species.

Sampling gear also affects the estimates of fecundity. Possenti *et al.* (2007) observed that the number of eggs of female *P. edwardsii* collected using traps was higher than those of the females caught by trawling. In the present study samples of shrimps were collected from landings of the commercial deep-sea trawling operation, therefore the actual fecundity of *P. quasigrandis* may be higher than the present estimates. Suseelan (1974) studied the fecundity and egg size of *P.quasigrandis* off south west coast of India and reported the average fecundity of 3972 eggs (1818- 7469 eggs) and egg size of 0.75-0.96 mm. Comparable fecundity range was also observed in this study. However, a lower average fecundity and higher size of egg was obtained in the present study.

Considerable egg loss during the incubation process was observed in *P.quasigrandis* as reported in the many pandalid shrimps (Ito, 1976; Ohtomi, 1997; Ahamed and Ohtomi, 2011). The egg loss observed in the present study (41%) is within the range reported by Oh and Hartnoll (1999) for caridean shrimps. In caridean shrimps egg loss during incubation period normally happens in environment and may be induced by numerous factors such as mechanical injuries due the fishing operations, aborted development, parasites, maternal cannibalism, embryo predation (Blasundaram and Pandian, 1982; Kuris, 1991). According to Lardies and Wehrtmann (2001) the increment of egg size during the incubation period is one of the main reasons for the egg loss, as the physical space existing under the abdomen for egg attachment is a limiting factor for egg production in caridean shrimps.

Reproductive output of crustacean species was influenced by population structure, food availability, female body size, egg loss, egg size, seasonal variation and habitat adaptation (Boddeke, 1982; Mantelatto and Fransozo, 1997). The annual mean reproductive output of *P.quasigrandis* was less than other deep-sea pandalid shrimps (Maiorano *et al.,* 2002; Chilari *et al.,* 2005; Echeverria *et al*., 2011). According to Chul *et al.,* (2008) lower reproductive output could be advantageous to larval survival since more energy can be invested to individual eggs. The present study also showed that, RO was lower than fresh water palaemonid shrimps which ranged from 12–27% (Jong *et al.*, 2008). According to Anger and Moreira (1998) the marine caridean shrimps species have significantly lower RO than freshwater shrimps.

Reproductive load which is the ratio between size at first maturity and asymptotic length was determined to gain an insight in to the correlation between growth and reproduction of these individuals (Froese and Pauly, 2000). According to Pauly (1984) the reproductive load usually falls between 0.4–0.9 and is relatively constant within taxa of organisms of approximately similar dimensions. In the present study the value of reproductive load of female *P.quasigrandis* (0.58) was observed in the normal range. Jayawardane *et al*. (2003) reported comparatively lower value (0.54) of reproductive load in coastal penaeid shrimp *Metapenaeus dobsoni* from Sri Lankan waters. Relatively high reproductive load of *P.quasigrandis* was probably due to the relatively higher length at first maturity.

Success and efficiency of closed season is highly dependent on the information on major spawning season of a species in a population. The continuous breeding pattern observed in *P. quasigrandis* throughout the year was similarly reported in the other *Plesionika* species (Company and Sarda, 1997; Maiorano *et al.*, 2002; Ahamed and Ohtomi, 2011). Company and Sarda (1997) observed ovigerous females throughout the year in *P. heterocarpus* and it was always higher than 60%. Extensive reproductive period appears to be a unique feature of species distributed in deep bottoms, where environmental conditions are constant (Tyler, 1988).

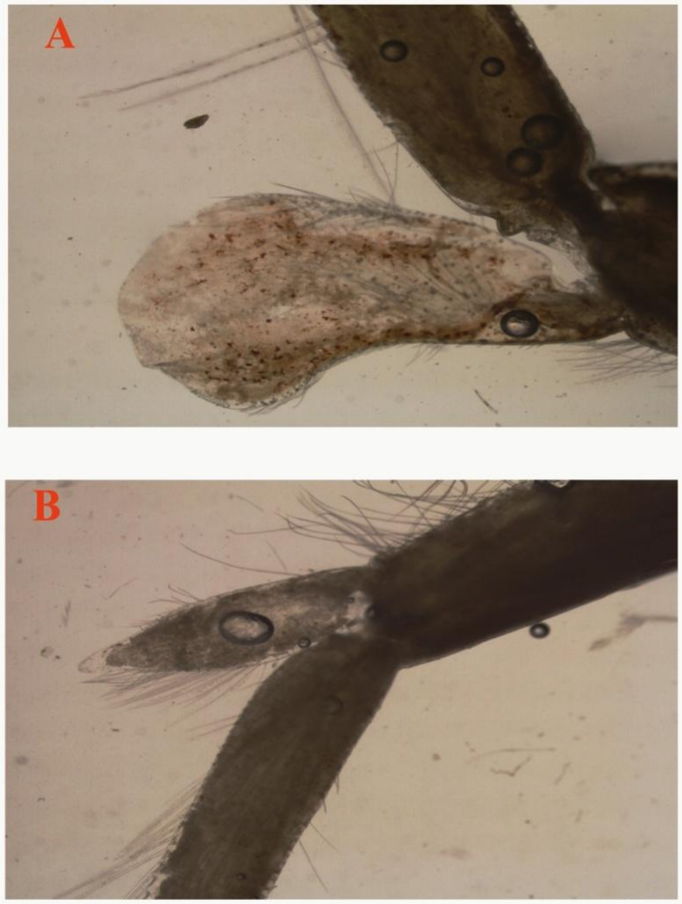


Figure 6.1. The shape of endopod of the first pleopod (A= male, B= Female)

Figure 6.2. Second pleopod with masculine appendix of the adult male.

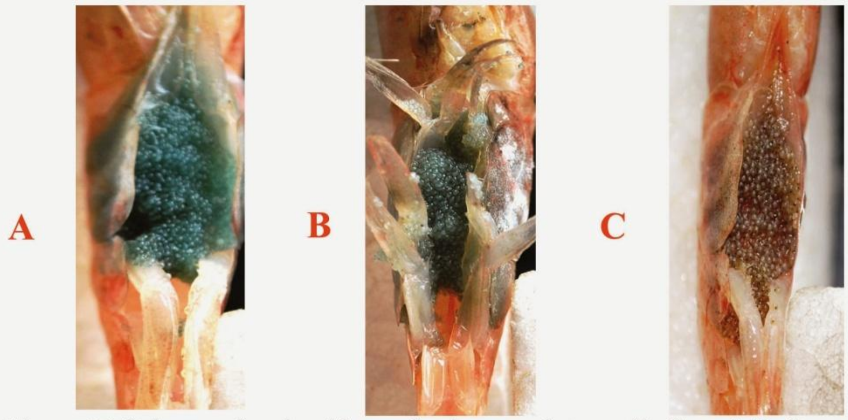


Figure 6.3. Ovigerous female with egg developmental stages (A=Stage I, B=Stage II, C=Stage III).

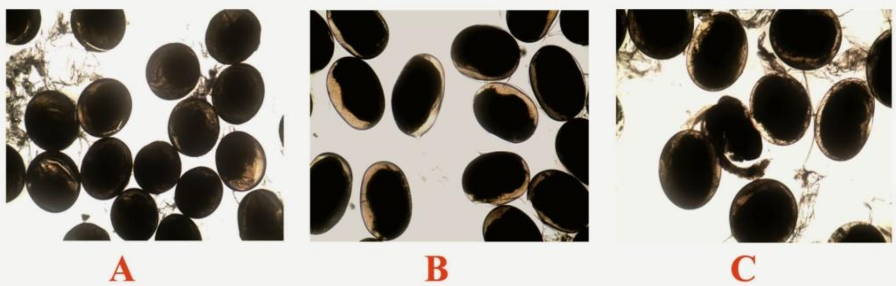


Figure 6.4. Egg developmental stages observed under microscope.

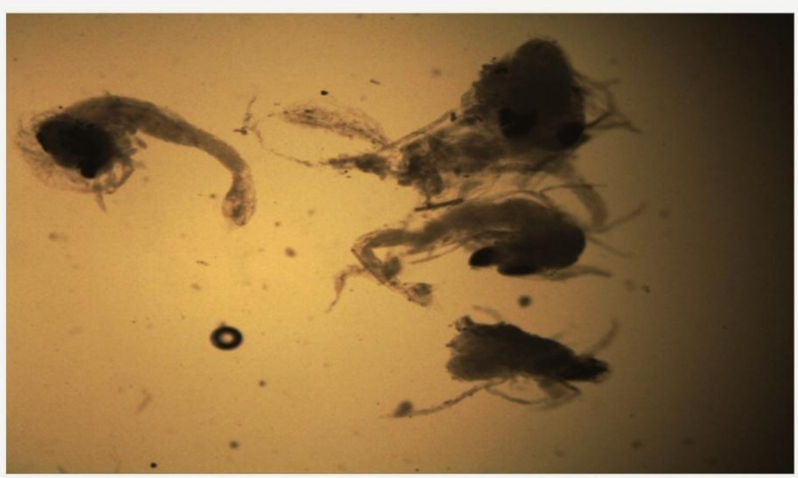


Figure 6.5. Newly hatched larvae observed in the ovigerous individual with late egg developmental stage (stage III).

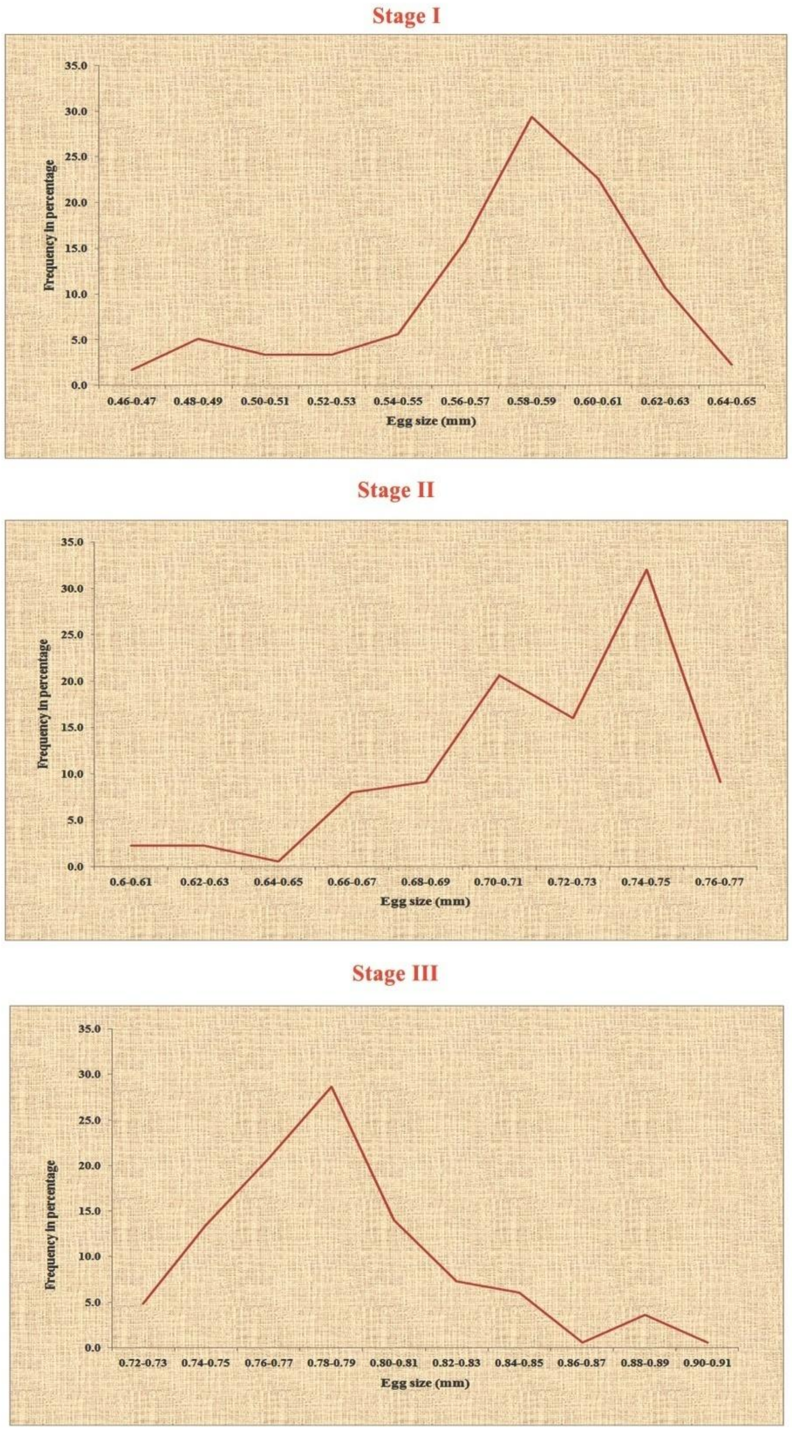


Figure 6.6. Egg size frequency distribution of egg development in *Plesionika quasigrandis*

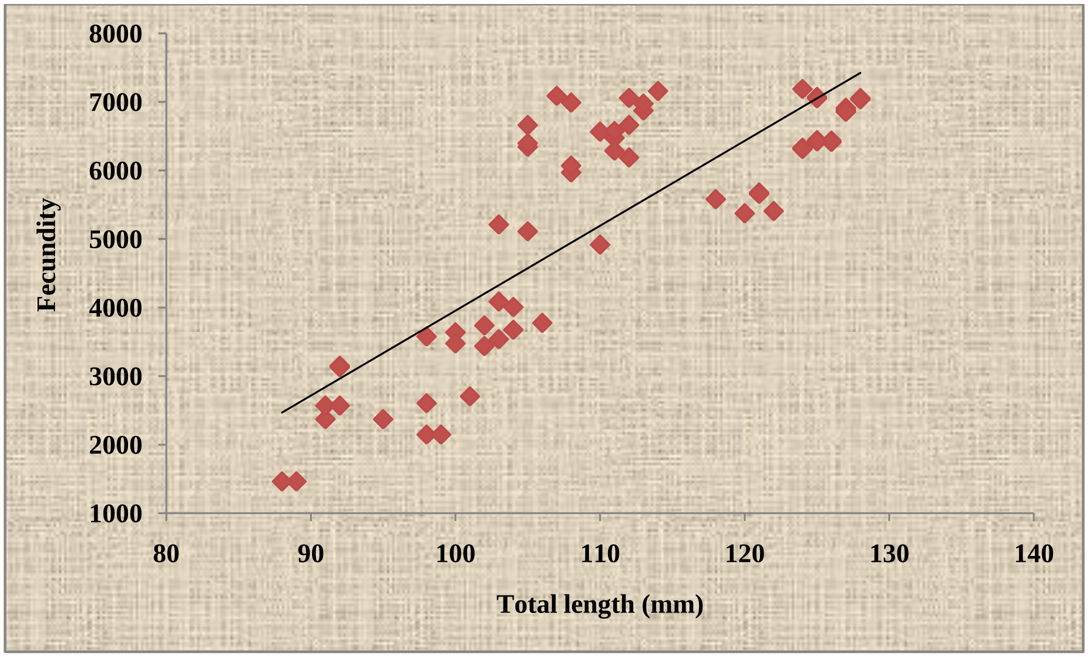


Figure 6.7. Relationship between total length and number of eggs in *Plesionika quasigrandis*

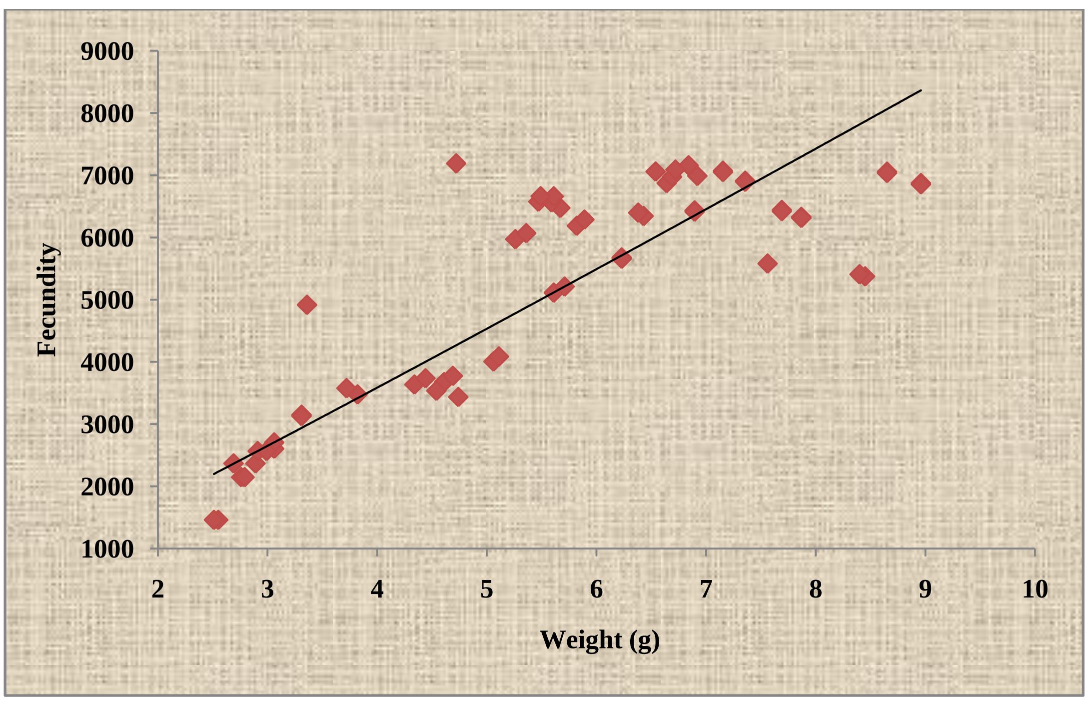


Figure 6.8. Relationship between weight and number of eggs in *Plesionika quasigrandis*

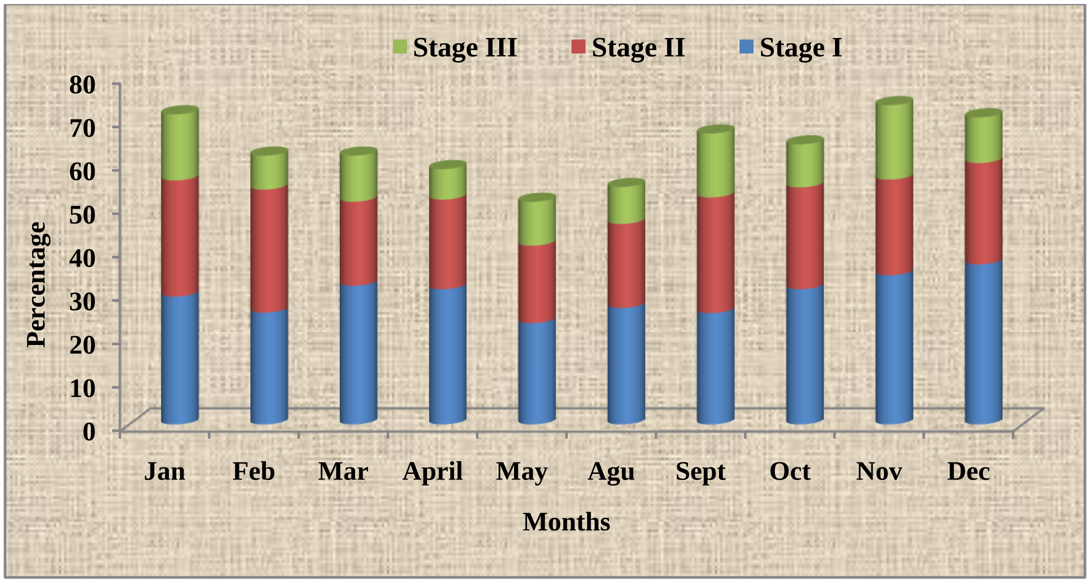


Figure 6.9. Monthly percentage contribution of ovigerous females with three egg development stage during 2010

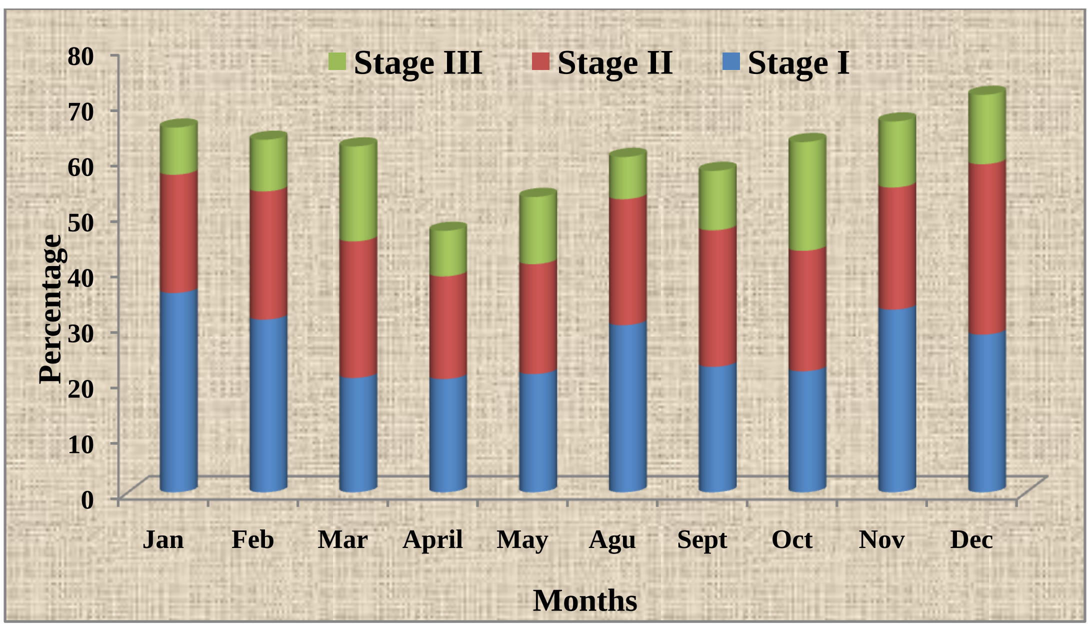


Figure 6.10. Monthly percentage contribution of ovigerous females with three egg development stages during 2011

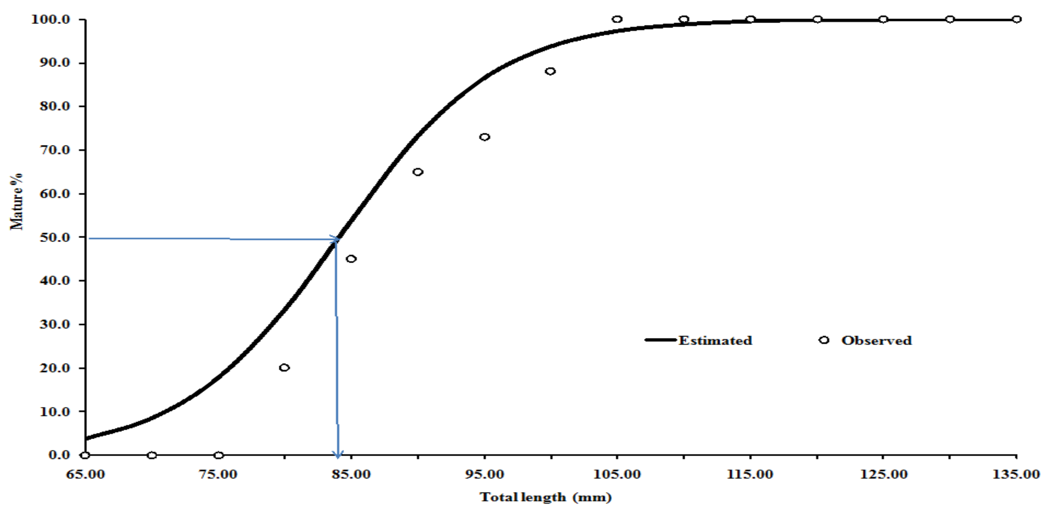


Figure 6.11. Length at first maturity of female *Plesionika quasigrandis*

Chapter 7

Food and feeding

7.1 Introduction

Stomach content analysis provides general information on the food items consumed by the organism which will be helpful in assessing the geographical, seasonal and diurnal variations in the composition of food and the rate of feeding. Stomach content analysis and feeding habit studies of organisms have been considered as one of the most significant subjects in the ecology of marine communities (Kostas Kapiris, 2012). The study also helps to determine the niche in the ecosystem and hence, it is desirable to study the food and feeding habits as a part of fish biology. Data on the feeding habits of an organism is essential for developing ecosystem based fisheries management models (Hanson and Chouinard, 2002; Kublicki *et al.*, 2005).

Feeding habits of aquatic organisms vary from season to season. The seasonal variations in temperature also influence rate of food consumptions and digestion. Diet of most of the species changes during different life stages and particularly during the spawning period. Knowledge on the diets and feeding habits of aquatic organisms provides the basis for understanding the trophic interactions in aquatic food webs (Vander Zanden and Rasmussen, 2002). Food is considered as the main limiting factor in the functioning of deep-sea ecosystems (Jumars and Gallagher, 1982). Generally aquatic organisms have been described as opportunistic feeders and feed on a large variety of prey (Cortes, 1999).

Feeding habits of the commercially important deep-sea Aristeid shrimps

Aristeus antennatus and *A. foliacea* are well described (Cartes and Sarda, 1989; Cartes, 1994; Kapiris *et al.*,1999; Kapiris, 2004; Chartosia *et al.*, 2005; Cartes *et al.*, 2008; Kapiris and Thessalou, 2011). Maynou and Cartes (1998) gave an account on daily ration estimates and made comparative study of food consumption in deep-sea decapods in the Mediterranean Sea and indicated that body shape and trophic diversity account for most of the variability in the quantity of prey fed by decapods. Cartes (1993) provided information on the day-night feeding habits of deep-sea decapod crustacean species. Detailed studies on food and feeding habits of *Plesionika martia, P. gigliolii, P. edwardsi, P. heterocarpus, P. acanthonotus* and *P. narval* are carried out (Fanelli and Cartes,2004; Kitsos *et al.*, 2008). Fanelli and Cartes (2004) described the diet composition and influence of environmental and biological factors on the feeding habits of *P. heterocarpus* , *P. martia*, *P. gigliolii* and *P. edwardsii* and the study pointed out that deep bathyal species consumed mainly mesopelagic resources, while the shallow living species such as *P. heterocarpus* consume mainly benthic organisms.

Information on feeding habits of deep-sea shrimps from Indian waters is scanty. Preliminary information was collected on the feeding habits of *Penaeopsis jerryi, P. philippi* and *P. rectacutus* (Kurian, 1964 and 1965) and on deep-sea pandalid shrimp species collected during the exploratory surveys off south-west coast of India (Suseelan, 1974). Detailed studies on natural diet and feeding habits of the pandalid shrimps *Heterocarpus gibbosus* and *H. woodmasoni* collected from the commercial landings in the Kerala coast and during the exploratory surveys off south-west coast of India were also carried out (Radhika, 2004). No published information is available on the feeding habits of *Plesionika quasigrandis* and the present study provides information on general diet composition, monthly and sex wise variation of food items and feeding intensity.

7.2 Materials and methods

Shrimp samples were collected from Sakthikulangara, Vypin and Cochin Fisheries Harbour during the period January 2010 to December 2011. Total length, weight and sex of specimens from each sample were recorded. In females diet compositions of ovigerous and non-ovigerous specimens were separately recorded. Stomachs of collected shrimps were dissected out, weighed and stomach fullness was recorded. The stomach contents were emptied into a petridish and examined under a binocular microscope.

Stomach contents of shrimps could rarely be identified due to the nibbling action of mandibles on the food and mastication of food inside the stomach by the action of gastric mill. Hence identification of various food items was based mainly on broken shell remains, spines, and setae. Stomach condition was expressed as full, 3/4 full, 1/2 full, ¼ full, trace and empty. Month wise feeding condition and index of preponderance values were calculated separately for male, ovigerous and non-ovigerous females. The 'points method' (Pillay, 1952) was used where amount of diet in the stomach was very little. In order to get a clear picture of frequency of occurrence as well as volume of various items, 'Index of Preponderance' method (Natarajan and Jhingran, 1961) was used.

Index of preponderance $I = \frac{Vi\ Oi}{\Sigma\, Vi\ Oi} x100$

Vi = Percentage of volume

Oi = percentage of occurrence

7.3 Results

7.3.1 General diet composition

Various components in the stomach content were identified and categorized into the following groups: crustacean remains, fish remains, molluscan shells, detritus, foraminifera and euphausiids. Annual index of preponderance is shown in Fig.7.1. Detritus formed the most important food component with an index of 38.09 which mainly consists of semi digested plant and animal matter and decayed organic matter. Crustacean remains (Index 21.22) were the second important prey item among the stomach content and it includes decapod parts such as appendages and body parts of shrimps and crabs and other unidentifiable crustacean parts.

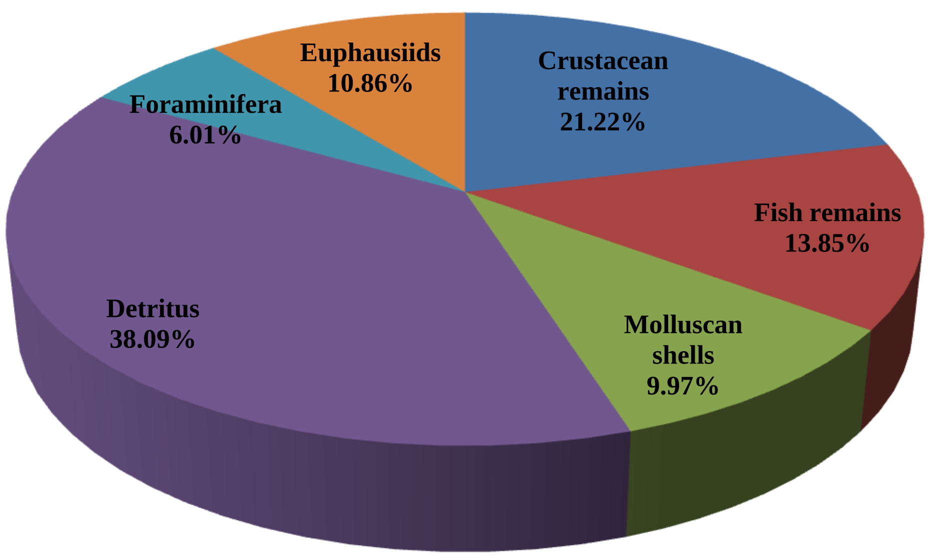


Figure 7.1. Annual index of preponderance of food items in the stomach of *Plesionika quasigrandis*

Fish remains (Index 13.85) were present mostly as bones, scales and spines in broken condition. The molluscan shells (Index 9.97) consisting of bits of small bivalve and gastropod shells also formed part of the diet. Euphausiids contributed with index of 9.97. However, foraminifera occurred only in a small percentage (6.01%) of total food items.

7.3.2 Diet composition in male, ovigerous and non-ovigerous females

Index of Preponderance indicates that detritus contributed a significant part of stomach contents of male (42.70) and non ovigerous females (41.17), whereas in the ovigerous females it contributed with the index of 30.38. Crustacean remains formed higher proportion in ovigerous females (26.42) than in males (17.17) and non- ovigerous (20.05). The quantity of euphausiids in males was less in comparison with females. Foraminifera formed a minor diet items in all groups (Table 7.1). The quantity of euphausiids was almost similar in both ovigerous and non-ovigerous females.

Table 7.1. Index of preponderance of food item in male, ovigerous and non-ovigerous females of *Plesionika quasigrandis*

Food items	Male	Ovigerous female	Non- Ovigerous females
Crustacean remains	17.17	26.42	20.05
Fish remains	14.29	15.19	12.07
Molluscan shells	10.12	10.28	9.51
Detritus	42.70	30.38	41.17
Foraminifera	5.61	5.98	6.43
Euphausiids	10.12	11.72	10.74

7.3.3 Month wise variation in diet composition

Monthly variation in the diet composition of male, ovigerous and non-ovigerous females based on the index of preponderance values are given in the Table 7.2, 7.3 and 7.4. All food items were observed in all months with the detritus and crustacean remains as the most predominant. The ranking of different food items based on the index of preponderance showed significant monthly variations in diet composition.

In males, detritus ranked first in every month except December with index value of above 50 during March and October. Crustacean remains were the second dominant food items and highest value was observed during December (28.13). In October, the crustacean remains was comparatively less (10.34). During February, fish remains were the second dominant food item. Similar trend was observed during May and October also. Molluscan shells recorded a peak during April (18.42) followed by August (11.61) and February (10.79). In January, the monthly value of euphausiids was highest (14.68), while it was represented in small quantities during August (4.52) and October (5.2). Foraminifera was observed in small quantities in almost all the months except during December.

Table 7.2. Index of preponderance (Month wise) of food item in male *Plesionika quasigrandis*

Months	Crustacean remains	Fish remains	Molluscan shells	Detritus	Foraminifera	Euphausiids
January	18.2	14.34	9.25	38.32	5.21	14.68
February	15.62	20.3	10.79	39.01	5.9	8.38
March	15.83	11.29	7.56	53.1	2.1	10.12
April	11.6	8.96	18.42	38.87	8.2	13.95
May	14.22	19.12	8.5	43.29	3.42	11.45
August	21.8	17.6	11.61	41.76	2.71	4.52
September	21.19	11.85	10.39	43.43	3.83	9.31
October	10.34	15.17	9.38	52.61	7.3	5.2
November	14.73	12.42	7.81	49.7	6.1	9.24
December	28.13	11.88	7.5	26.89	11.3	14.3

In ovigerous females, crustacean remains were dominant during April (33.25), May (23.31), September (30.01), November (25.87), December (34.64) and during the remaining months large part of the diet was contributed by detritus. Lowest index of preponderance values for detritus and crustacean remains was noticed during November (21.6) and August (18.39) respectively. Fish remains was the second dominant food item during August (23.34) and the lowest index was observed in February (10.12). Highest index value for molluscan shells was recorded in September (12.79) and May (12.65), lowest in August (7.27). The index value of foraminifera was below 10 throughout the year with maximum in May (9.7) and minimum in March (3.06). Highest quantity of euphausiids was found during November (15.2) followed by October (14.12), May (13.77) and August (12.3). Least occurrence of euphausiids was during April (5.76).

Table 7.3. Index of preponderance (Month wise) of ovigerous female *Plesionika quasigrandis*

Month	Crustacean remains	Fish remains	Molluscan shells	Detritus	Foraminifera	Euphausiids
January	25.25	11.98	11.52	34.16	6.06	11.03
February	27.71	10.12	9.99	33.5	5.15	13.53
March	22.01	16.86	10.05	40.03	3.07	7.98
April	33.25	12.01	11.9	31.52	5.56	5.76
May	23.31	17.65	12.65	22.92	9.7	13.77
August	18.39	23.34	7.27	31.48	7.22	12.3
September	30.01	10.62	12.79	26.3	8.9	11.38
October	23.83	18.29	8.56	32.1	3.1	14.12
November	25.87	19.96	9.42	21.6	6.95	16.2
December	34.64	11.12	8.69	30.23	4.1	11.22

In non-ovigerous females, occurrence of detritus as food item with high index value was observed in all the months except February and November. Maximum detritus was observed during April (54.61) and minimum during

February (25.4). During February and November, crustacean remains were the dominant food item and the index of preponderance value was 26.89 and 31.76 respectively, fish remains formed significant portion of the food items mainly during August (19.3) and November (16.6) and it was observed in minor quantities during September (8.85) and October (8.2). The proportion of molluscan shells as food item was almost similar to the fish remains in various months and greatest quantity was observed during December (13.42) and minimum during April (6.38). Foraminifera occurred in considerable proportions only during February and the index value was below 10 in all other months.

Table 7.4. Index of preponderance (Month wise) of non-ovigerous female *Plesionika quasigrandis*

Months	Crustacean remains	Fish remains	Molluscan shells	Detritus	Foraminifera	Euphausiids
January	16.31	12.71	10.15	42.37	6.19	12.27
February	26.89	10.7	12.16	25.45	11.67	13.13
March	20.15	11.35	7.5	47.27	4.32	9.41
April	14.34	11.17	6.38	54.61	7.3	6.2
May	16.73	10.42	8.28	50.21	6.1	8.26
August	14.91	19.33	11.25	35.62	5.21	13.68
September	23.3	8.85	8.87	39.94	7.38	11.66
October	18.89	8.2	7.56	51.32	3.64	10.39
November	31.76	16.6	9.61	28.8	5.71	7.52
December	17.3	11.39	13.42	36.14	6.82	14.93

7.3.4 Feeding intensity

Annual feeding intensity in percentage of *P. quasigrandis* is presented in the Fig.7.2. Annual feeding condition showed high percentage of empty stomachs and the proportion was 46.02% (pooled). Percentage of full stomach was comparatively low in case of non-ovigerous females (3.5%) than ovigerous females (4.47%) and males (5.54%). Occurrence of trace and ¼ full stomachs showed almost similar percentage for all the groups. Only 8.04% of male were observed with ½ full stomachs, while the percentage of females with ½ full stomachs was higher compared to male.

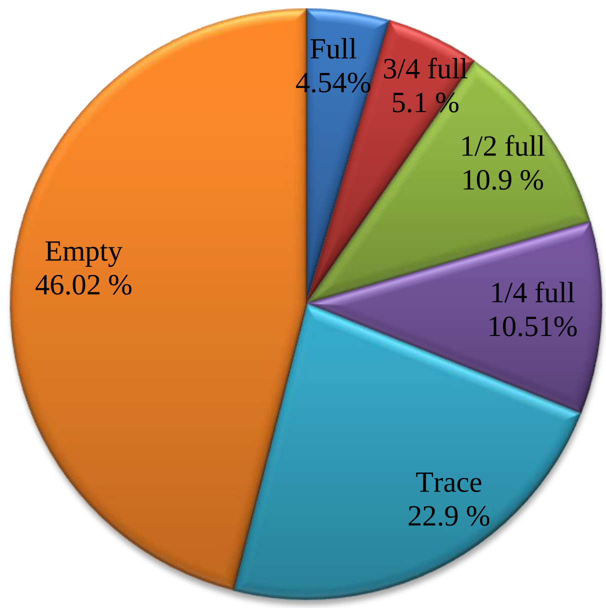


Figure 7.2. Annual feeding intensity of *Plesionika quasigrandis*

Monthly variations in fullness of stomach of males, ovigerous and non-ovigerous females were analysed and results presented in Fig.7.3, Fig.7.4 and Fig.7.5. The occurrence of trace and empty stomachs was noticed throughout the year in all the groups. Maximum percentage of empty stomachs was observed during November for males (58.6%) and ovigerous females (62.65%), December for non-ovigerous females. However, lowest percentage of empty stomachs was observed during February (34.63%), August (38.8%) and April (37.31%) for male, ovigerous and non-ovigerous females respectively.

In males, maximum percentage of full stomach was observed during August

(10.8%), but absent during May. Maximum percentage of occurrence of ¾ full stomach was noticed during February (16.06%) while it was slight in January (3.43%). Presence of ½ full stomachs were noticed in all the months except May, with highest percentage of occurrence in December (18.61%). Predominance of ¼ full stomach was recorded during October (16.2%) and lowest during November (6.4%).

In case of females, the percentage of full stomach was high during April (7.43%) for ovigerous and during March (7.4%) for non-ovigerous females. Occurrence of ¼ full stomachs was totally nil during December and January for ovigerous and non-ovigerous females respectively. Presence of ½ full stomach was recorded throughout the year for non-ovigerous, though absent during September for ovigerous females. Dominance of ¾ full stomachs was noticed in April and August with percentage values of 6.4% and 10.2% in ovigerous and non- ovigerous females.

7.4 Discussion

Decapod crustaceans live in a lower trophic level and appear to be opportunistic omnivores, consuming diet mainly from the bottom of their habitats (Williams, 1981). Generally crustacean decapods have been considered as scavengers or detritivores (Gage and Tyler, 1992). In the current study high percentage of detritus was observed in the stomach contents which are similar to those reported for other deep-sea shrimp species (Donaldson, 1975; Weinberg, 1980; Burukovskij, 1992; Karuppasamy and Menon, 2004). The protein-energy ratio was highest in the detritus than any other factor in the biota (Julian *et al.*, 2003). Bacteria associated to the detritus may serve as a source of food in that the bacterial protein, released upon cell lysis, may be utilized by the shrimp (Hood and Meyers, 1974). The index of preponderance value observed for the species showed that it is an opportunistic feeder.

Crustacean remains was the second dominant food item in the shrimp and the results are comparable to those reported in other *Plesionika* species such as *P. heterocarpus, P. ensis, P. martia* (Mary and Ioannis, 1999; Fanelli and crates, 2004). Rainer (1992) reported that crustaceans was dominant food item in the stomach of deep-sea aristeid shrimp *Aristaeomorpha foliacea* and *Plesiopenaeus edwardsianus* and pandalid shrimp *Heterocarpus sibogae.*

Euphausiids and foraminifers were observed equally in most of the months in both sexes. Euphausiids were in fourth position in the food items of *P.quasigrandis*. This observation differ from some previous studies, which indicated that euphausiids were one of the dominant food items in stomachs of the deep-sea shrimps *P. heterocarpus*, *P. edwardsii*, *H. gibbosus* and *H. woodmasoni* (Fanelli and crates, 2004; Radhika, 2004). Higher proportion of foraminifera was observed in stomach of *H. sibogae* collected during night time (Rainer, 1992). Mary and Ioannis (1999) also reported high percentage of foraminifera in stomach of deep-sea rose shrimp *Parapenaeus longirostris.*

There was significant difference in diet percentage composition between ovigerous and non-ovigerous females. The crustacean remains was observed to be higher in ovigerous females than in male and non-ovigerous females. Monthly variation in diet composition indicated no specific trend in the seasonal preference to any diet item.

Deep-sea environment is characterized by ecological stability and relative scarcity of available food resources (Tyler 1988). The overall percentage of empty stomach was high during the present study. Generally shrimps spend the day buried in the substratum and are more active at night. Most of the shrimps showing nocturnal feeding habit feeds several times during night due to their small stomach and obtain sufficient food (Kostas Kapiris, 2012). Shrimp with high percentage of empty stomach in landing might be due to the nocturnal feeding behavior of species and for this species fishing is performed only during the day time (chapter 3). Retention time of various food items in stomach of crustaceans varied and the hard parts such as bone and shell was retained for longer time than fleshy tissue. In deep-sea decapods digestions occur rapidly and the food items are retained in the stomach only for a few hours (Omori, 1974; Roe, 1973).

Generally high percentage of empty stomachs is an indication of low feeding rate or high metabolic rates (Kapiris, 2004; Company, 1995). The low feeding condition in deep-sea decapod crustaceans has been reported earlier (Wenner, 1979; Cartes and Abello, 1992; Fanelli and Cartes, 2004) and appears to be a common pattern for such species as an adaptation to the deep-sea environment, where trophic resources are scarce. High incidence of empty stomach was reported in the deep-sea pandalid shrimp *P. edwardsii* (48%), *P. martia* (40%), *P. ensis* (34.6%) *H. sibogae* (21%) and *H. woodmasoni* (94%) (Rainer, 1992; Mary and Ioannis, 1999; Fanelli and Cartes, 2004)

Feeding intensity is presumed to low in ovigerous females when compared to males and non-ovigerous females and these findings agree with that of observation made in *P. gigliolii* and *P. martia* (Fanelli and Cartes, 2004). The stomach fullness varied monthly and the percentage of highest empty stomachs was observed during October, November, December and January and these findings coincided with peak breeding season of this species.

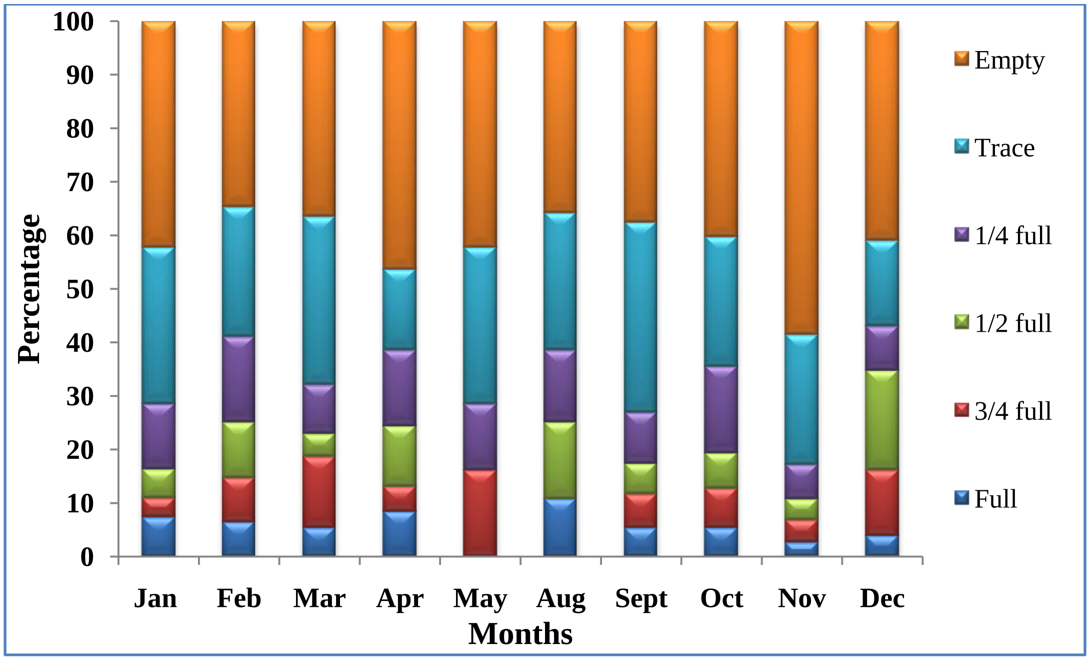


Figure 7.3. Monthly feeding intensity of male *Plesionika quasigrandis*

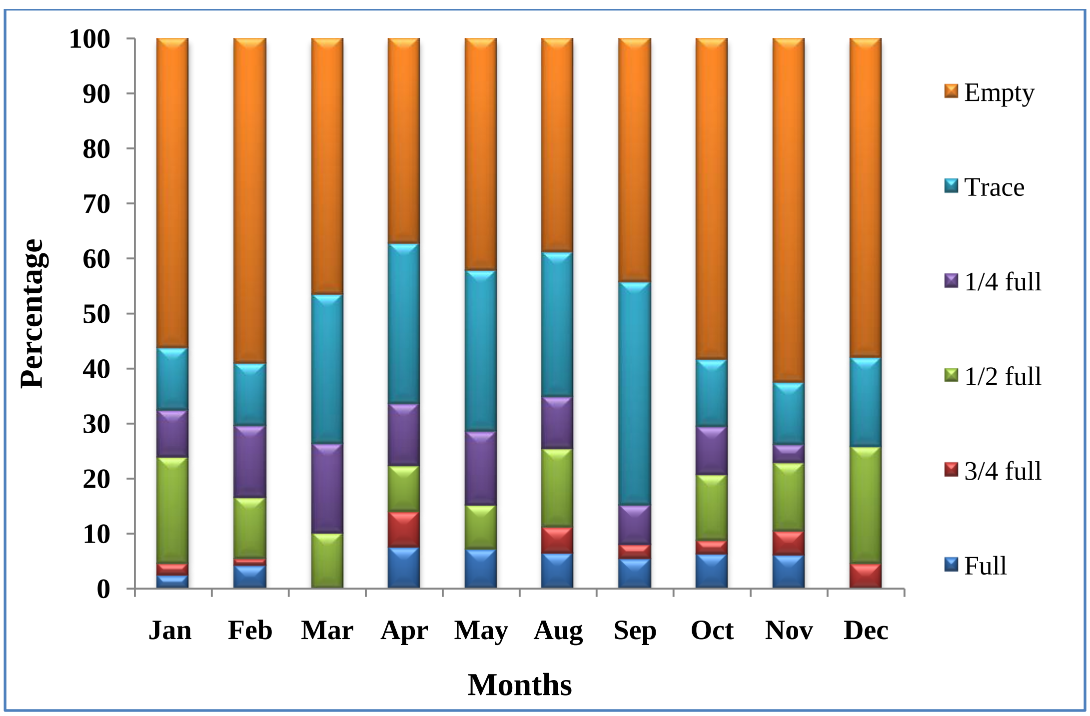


Figure 7.4. Monthly feeding intensity of ovigerous female *Plesionika quasigrandis*

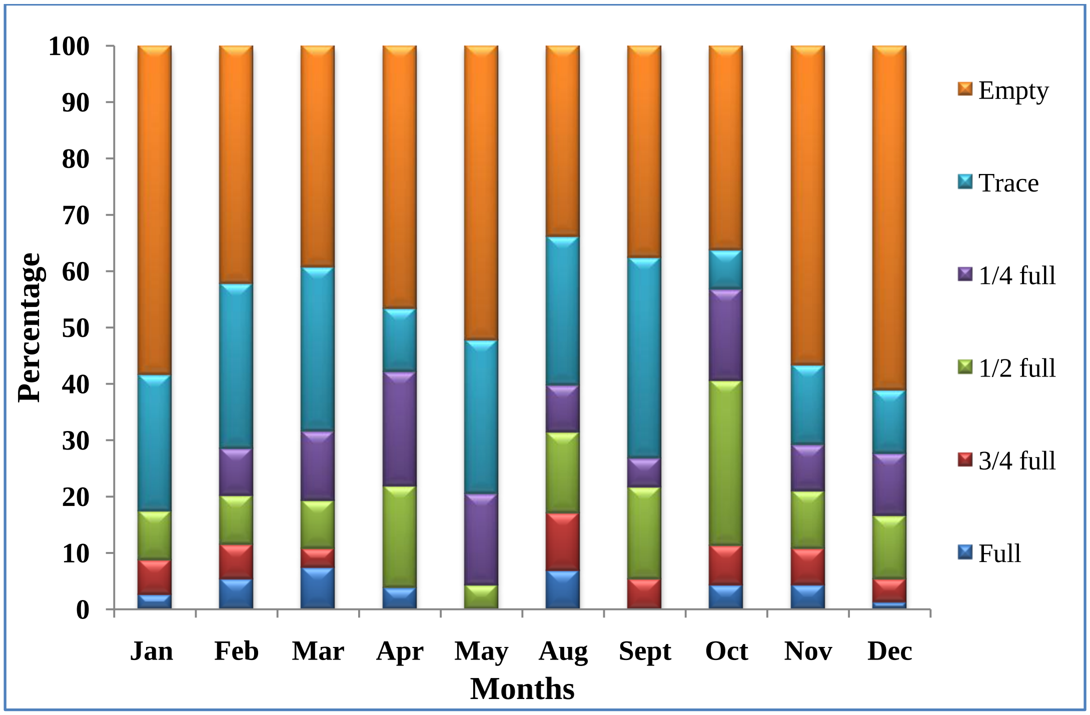


Figure 7.5. Monthly feeding intensity of non-ovigerous female *Plesionika quasigrandis*

Chapter 8

Age and Growth

8.1 Introduction

The study of age and growth is an important and essential aspect of fishery biology and management. This information is required for proper understanding of age class structure of the stock. Determination of the age and growth of a species further helps in the study of biological characteristics such as longevity, rate of growth, age at first maturity and age structure of the stock. Knowledge of these aspects is also essential to determine the mortality and survival rates of various length classes and the success of the yearly broods all of which contribute to a rational and sustainable management of the stocks (Seshappa, 1999). The growth rate is variable because it is greatly dependent on a number of biotic factors such as age, maturity, food quality and quantity and presence of the predators. It is also influenced by abiotic factors, such as temperature, photoperiod, dissolved oxygen and salinity (Dall *et al.*, 1990). All these factors interact with each other to influence the growth rate.

Age in most of the aquatic animals can be calculated by counting annual growth bands deposited in hard structures such as the otoliths of fishes (Campana, 2001) and shells of bivalves (Kilada *et al.*, 2009). Crustaceans do not retain any morphological evidence of age or growth throughout their lifespan. Crustacean growth is discontinuous and dependent on moult frequency and moult increment (Lizarraga *et al.*, 2008). All hard structures are shed with each moult and this lack of bony material has posed a major problem in identifying chronological age in these animals. The duration of the moult cycle depends on species and size, and it influences the morphology, physiology and behavior of these animals (Bureau *et al.*, 2000). Traditionally tagging and recovery method has been used for age determination of shrimps (Eltershank, 1984). Recently some attempts were made for detection of growth bands in calcified regions of the eyestalk and gastric mill in shrimps, crabs, and lobsters (Raouf *et al.,* 2012), lipofuscin assay (Bluhm and Brey, 2001; Katelyn, 2008) and use of chemical body composition and energy content (Hopkins *et al.,* 1989). Despite these efforts the most widely used method of determining growth in shrimps is based on length frequency distribution. Generally the basic Von Bertalanffy growth (VBG) equation (Von Bertalanffy, 1938; Beverton and Holt, 1957) is then fitted by a variety of methods to the mean lengths of these cohorts in relation to their age.

A considerable amount of information is available on the age and growth of coastal shrimp species in India (Lalitha Devi, 1986; Suseelan and Rajan, 1989; Sukumaran *et al.,* 1993; Nandakumar, 1997; Dineshbabu and Joseph, 2007; Maheswarudu *et al.,* 2011; Pillai *et al.,* 2012; Pillai and Thirumilu, 2013), but the only available information of growth parameters of deep-sea shrimp is on *Heterocarpus woodmasoni* and *H. gibbosus* reported from Kerala coast (Radhika, 2004). Company and Sarda (1997) described age and growth details of five *Plesionika* species (*P. acanthonotus, P.edwardsi, P. gigliolii, P. heterocarpus and P. martia*) from Western Mediterranean sea based on the samples collected by trawl survey at depths ranging from 150 to 1100 m. Chilari *et al*. (2005) recorded the information on growth parameters and reproductive biology of *P.martia* from eastern Ionian Sea. The growth characteristics and biological aspects of

P. edwardsii from Mediterranean Sea have been given by Colloca (2002) and Garcia *et al*. (2000). Maiorano *et al.* (2002) studied the life history traits of *P.martia* by experimental bottom trawl surveys carried out in the western Ionian Sea. The detailed biology and growth of *P. martia* from Aegean Sea is accounted by Cengiz *et al*. (2012). Ohtomi (1997) reported detailed account of the growth parameters of *P. semilaevis* from Japan waters. Age and growth of *P. narval* was investigated by Gonzalez *et al.* (1997) and Arculeo and Lo (2011) from Canary Island and Southern Tyrrhenian Sea respectively using samples collected from commercial traps. In the present work an attempt has been made to study in detail the age and growth of the deep-sea pandalid shrimp *P. quasigrandis* based on length frequency methods.

8.2 Materials and Methods

Samples of *P.quasigrandis* were collected from Sakthikulangara, Vypin and Cochin Fisheries Harbours along the Kerala coast during January 2009 to December 2011. Samples were sorted sex wise and length and weight recorded. Total length is measured in mm using digital calipers and grouped into 5 mm class intervals for length frequency analysis. The length-frequency distribution in the sample was raised to the total catch on the sampling day based on the sample weights. The data thus obtained for different sampling in a month were pooled to get catch in numbers for all the sampling days which in turn, were raised to the monthly catch. Growth parameters were estimated separately for males, females and pooled samples. A total of 2462 samples ranging in size from 62 to 132 mm total length comprising of 1147 males and 1315 females were used for growth parameter studies.

The Von Bertalanffy growth formula (VBGF) (Von Bertalanffy, 1938) was used to describe the growth. It is the most widely used growth model in fish stock assessment which has been shown to conform to the observed growth of most species. The equation can be written as:

$L_t = L_\infty \, [1 - e^{-K\,(t - t_0)}]$

Where:

L_t = mean length at age t

K = the growth coefficient

L_∞ = the asymptotic length

t_0 = theoretical age at zero length

Growth parameters L_∞ and K were estimated using FAO-ICLARM Stock Assessment Tools (FiSAT II) (Gayanilo *et al.*, 2005). For a preliminary arbitrary estimate of L_∞, Powel-Wetherall method was used. The L_∞ thus obtained was used as input for scan of K values in ELEFAN I.

The t_0 is also required for the calculation of growth in length using VBG equation. For this purpose an approximate value of t_0 was estimated from Pauly's empirical equation (Pauly, 1979).

$\text{Log}\,(-t_0) = 0.392 - 0.275 \log L_\infty - 1.038K$

The longevity was calculated by using the equation ($t_{max} = 3/K$) derived by Pauly (1983).

The growth parameters obtained in the present study are compared with the available growth studies of the related species in the same family. Growth performance index (ø) was determined using the following formula (Pauly and Munro, 1984).

$$\Phi = \mathrm{Log}_{10} K + 2\,\mathrm{Log}_{10} L_{\infty}$$

Where K and L_{∞} are growth parameters

8.3 Results

8.3.1 Length frequency distribution and mean length

Total length (TL) varied from 62 to 132 mm and carapace length (CL) from 12–27 mm. The minimum (L_{mini}) and maximum (L_{max}) total length were 65 and 125 mm for males and 62 and 132 mm for females respectively with mean total length of 94 and 97 mm. The sex wise length frequency distribution of shrimp in different size groups is given in Fig. 8.1. In the pooled data (2009–11), more than 75% of males were belongs to five length groups (81–85, 86–90, 91–95, 96–100, 101–105 mm) and more than 80% of females were belongs to six length groups (86–90, 91–95, 96–100, 101–105, 106–110, 111–115 mm). In males, the modal size group in the fishery was 96–100 mm during the year 2009 and 2010, but in 2011 it was 91–95 mm. In the case of females the modal size group was 90–95, 96–100 and 86–90 mm during the year 2009, 2010, and 2011 respectively.

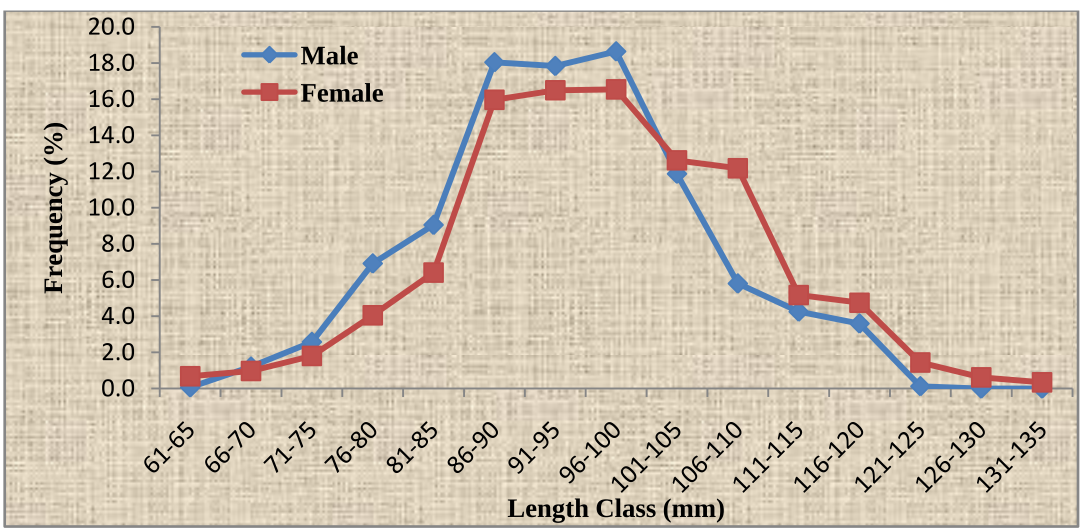


Figure 8.1. Sex wise length frequency distribution of *Plesionika quasigrandis* during 2009–2011

Mean total length of females was always greater than that of males. The annual mean length of male showed slight increase and varied from 93.5 mm in 2009, 94.3 mm in 2010 and 94.9 mm in 2011. In females the annual mean length increased from 96.4 mm in 2009 to 97.7 mm in 2010 and in 2011 mean length slightly decreased to 97.3 mm. The mean total length in the fishery attained a maximum in March for males (99 mm) and in December for females (103.3 mm). The smallest was observed in September for males (89 mm) and in August for females (91.3 mm).

8.3.2 Growth parameters L_∞, K and t_0

Male

The growth parameters of male *P. quasigrandis* were estimated using the monthly length data for the period 2009–11 by various methods given in Table 8.1. The preliminary estimate of asymptotic length (L_∞) obtained by Powell and Wetherall method was 131.2 (Fig.8.2). The calculated t_0 value for male shrimp was -0.0858.

Length frequency data was also analysed by the ELEFAN I programme, the resultant growth curves of which are presented in Fig.8.3. The L_∞ and K obtained from ELEFAN 1 with highest R_n value (0.211) were 139 mm and 0.68 respectively. The values obtained in ELEFAN I were substituted in the Von Bertalanffy's growth equation for male as given below.

Male: $Lt = 139\ [1 - \exp^{-0.68(t-0.0858)}]$

Longevity of male was calculated as 4.4 years and the length attained by male at the end of 1st, 2nd, 3rd and 4th year were estimated as 72.6 mm, 105.3 mm, 122 mm and 130.4 mm respectively. Fishery was sustained mostly by the 1 to 2 year old shrimps.

Female

The growth parameters of female shrimp estimated using the monthly length data for the period 2009–11 by various methods is given in the Table 8.1. The preliminary estimate of asymptotic length (L_∞) obtained by Powell and Wetherall method was 140.85 mm (Fig.8.4). The length frequency data was also analysed by the ELEFAN I programme, the resultant growth curves of which are presented in Fig.8.5. The L_∞ and K obtained from ELEFAN 1 with highest R_n value (0.236) were 145 mm and 0.52 yr^{-1} respectively.

The calculated t_0 value for female was -0.1002. The values obtained in ELEFAN I were substituted in the Von Bertalanffy's growth equation for female as given below.

Female: $Lt = 145 [1 - exp^{-0.52(t-0.1002)}]$

Table 8.1. Values of growth parameters analysed using different methods in the FiSAT program for male, female and combined sex for *Plesionika quasigrandis*

Method	Male			Female			Sexes Combined		
	L_∞	K	Z/K	L_∞	K	Z/K	L_∞	K	Z/K
Powell and Wetherall	131.2	-	3.9	140.8	-	3.7	137.4	-	3.6
ELEFAN I	139	0.68	-	145	0.52	-	143	0.61	-

Longevity of female calculated was 5.7 years and the length attained by the female at the end of 1st, 2nd, 3rd, 4th and 5th year were estimated as 63.2 mm, 96.4 mm, 116.1 mm, 127.8 mm and 134.8 mm respectively. Fishery was sustained mainly by the 1.5 to 3 year old shrimp. Average length attained by male and female shrimp given in the Table 8.2.

Combined sex

The growth parameters of combined sex of shrimps estimated by monthly length data for the period 2009–11 by various methods were given in the Table 8.1. The preliminary estimate of asymptotic length (L_∞) obtained by Powell and Wetherall method was 137.4 mm (Fig. 8.6). The length frequency data was also analysed by the ELEFAN I programme, the resultant growth curves of which are presented in Fig.8.7. The L_∞ and K obtained from ELEFAN 1 with highest R_n value (0.239) were 143 mm and 0.61 yr^{-1} respectively.

The calculated t_0 value for combined sex was -0.0926. The values obtained in ELEFAN I were substituted in the Von Bertalanffy's growth equation as given.

Combined sex: $Lt = 143[1 - exp^{-0.61(t-0.0926)}]$

Table 8.2. Average length attained by *Plesionika quasigrandis* at different ages

Age (Months)	Male (mm)	Female (mm)
6	45.7	38.9
12	72.6	63.2
18	91.7	81.9
24	105.3	96.4
30	115	107.5
36	122	116.1
42	126.9	122.7
48	130.4	127.8
54	132.9	131.7
60		134.8
66		137.1
72		138.9

Table 8.3. Comparisons of growth parameters reported by various authors for selected *Plesionika* species (Length-carapace length in mm)

Species	Sex	L_{max}	L_{∞}	K	φ	Area	Reference
P. acanthonotus	♂	16.2	18.4	0.5	0.233	NW. Mediterranean	Company & Sarda, 1997
	♀	17.9	19	0.55	0.129		
P.edwardsii	♂	27.2	32	0.8	0.84	NW. Mediterranean	Company & Sarda, 1997
	♀	29	31	0.65	0.697		
P.edwardsii	♂	26	28.8	0.8	2.73	W. Mediterranean	Garcia *et al.*, 2000
	♀	31	29.1	0.8	2.89		
P. gigliolii	♂	16	20	0.55	0.259	NW. Mediterranean	Company & Sarda, 1997
	♀	18.6	20.5	0.75	0.443		
P. heterocarpus	♂	19.4	22.4	1	0.621	NW Mediterranean	Company & Sarda, 1997
	♀	20.2	23	0.9	0.622		
P. martia	♂	23.9	27.5	0.54	0.491	NW. Mediterranean	Company & Sarda, 1997
	♀	26.7	30.4	0.39	0.44		
P. martia	♂		28	0.5	2.59	Mediterranean Sea	Maiorano *et al*., 2002
	♀		30.5	0.44	2.61		
P. martia	♂		28.2	0.53		Ionian Sea	Chilari *et a*l., 2005
	♀		30.6	0.31			
P. martia	♂	22.1	23.63	0.49	2.437	E. Mediterranean	Cengiz *et al.*, 2012
	♀	24.9	26.25	0.38	2.418		
P. narval	♂	28	29.5	0.54	2.67	Canary Island	Gonzalez *et al.*, 1997
	♀	30	31.9	0.66	2.84		
P. narval	♂		17.8	0.71	2.28	S .Tyrrhenian Sea	Arculeo & Lo, 2011
	♀		27.4	0.65	2.62		
P. quasigrandis	♂	25	28	0.68	2.72	Arabian Sea	Present study
	♀	27	30	0.52	2.66		

8.3.3 Comparison of growth parameters

The growth performance index was worked out separately for males, females and combined sex. In the present study the growth performance index was calculated using the asymptotic length in terms of carapace length and total length.

By using the asymptotic length (L_∞) in terms of total length, the growth performance index was 4.12, 4.03 and 4.09 for males, females and combined sex respectively. Whereas by using asymptotic length (L_∞) in terms of carapace length, the growth performance index was 2.72, 2.66 and 2.70 for males, females and combined sex respectively. The growth parameters in other *Plesionika* species given in Table 8.3.

8.3.4 Recruitment pattern

Recruitment is a complex progression involving a series of events in the life cycle of shrimps. The annual recruitment pattern is generated from the length frequency data and the corresponding growth parameters, by projecting each length frequency sample backward on a time axis. The growth parameters L_∞ (143 mm) and K (0.61) and t_0 (-0.0926) of combined sex were used for analysis. Recruitment to the fishery takes place throughout the year. The percentage of recruitment differed from 1.34% to 19.18% during the study period.

8.4 Discussion

The length range of *P. quasigrandis* observed in the present study different from previous study conducted in the same location (Rajan *et al.*, 2001; Radhika, 2004). The smallest animal observed in the fishery was 62 mm and 65 mm and the largest was 125 mm and 132 mm for male and female respectively. Dominant size class was 81–105 mm for males and 86–115 mm for females in the fishery. Rajan *et al.* (2001) reported that the fishery was supported by 71–120 mm with dominant size ranging between 86–105 mm for males and 76–120 mm with dominant size range of 86–110 mm for females in the beginning of the deep-sea shrimp fishery (1999–2000) along Kerala coast. But Radhika (2004) reported wider size class for males (51–150 mm) and for females (51–160 mm) which may be due to the fact that samples included shrimps from exploratory survey (FORV *Sagar Sampada*) along south west coast of India. Percentage of smaller sizes (<70 mm) were very less in the fishery which was estimated as 1.28% for males and 1.65% for females. Maiorano *et al.* (2002) observed that recruitment of *P. martia* occurred at the shallowest depths and juveniles moved to the deepest grounds as they grew. This may be one of the reasons for the low occurrence of smaller size groups of shrimp in the fishery during the present study. Mean size of females was slightly larger than males. The smallest mean length was observed in September for males and in August for females.

There is no previous published information on the growth parameters of *P. quasigrandis.* In the present study growth parameters $L\infty$ and K were estimated by Powell and Wetherall and ELEFAN I using length frequency data. The length frequency method for age determination is based on the assumption that the size distribution of any one age group will show very little variation around the modal length, thus making it possible to separate the successive age groups. $L\infty$ estimated by Powell and Wetheral method for male, female and combined sex is lower than the value obtained by ELEFAN I method. ELEFAN I method is described as more reliable and highly recommended objective method for studying single species dynamics in a multi species context (Pauly, 1982a). So the values of $L\infty$ (male- 139 mm, female- 145 mm, combined sex- 143 mm) and K (Male- 0.68 yr^{-1}, female- 0.52 yr^{-1}, Combined sex- 0.61 yr^{-1}) were used for further analysis and estimating population parameters.

A differential growth between the two sexes was noticed in the present study. L_{max} and $L\infty$ were higher in females than males. Higher value of $L\infty$ in females was previously reported in many *Plesionika* species (Ohtomi, 1997; Garcia *et al.*, 2000; Colloca, 2002; Cengiz *et al.*, 2012). Growth rate of deep-sea shrimps is slow when compared to coastal species. Growth coefficient value obtained in the present study is less than the value reported for coastal shrimp species in Indian waters (Dineshbabu and Joseph, 2007; Pillai *et al.*, 2012). Growth coefficient (K) value obtained shows similarity with the earlier reports of *Plesionika* species. Growth coefficient (K) value of five *Plesionika* species (*P. heterocarpus*, *P. edwardsii*, *P. giglioli*, *P. martia* and *P.acanthonotus)* from western Mediterranean waters ranged between 0.40 and 0.94 (Sarda, 2000). Growth coefficient (K) value of *P. quasigrandis* is higher in males (0.68 yr^{-1}) than female (0.52 yr^{-1}). Faster growth rate of male *P. martia* observed from Aegean Sea and Ionian Sea (Cengiz *et al.*, 2012; Chilari *et al*. 2005). High K value of male *P. edwardsi* was reported by Garcia *et al.* (2000). Growth coefficient value calculated in the present study is somewhat near to the value observed in the pandalid shrimp *H. woodmasoni* of Kerala coast (Radhika *et al.*, 2011).

Longevity of males and females estimated were 4.4 years and 5.8 years respectively. King and Butler (1985) observed that deep-sea shrimp species exhibit longer life span compared to shallow water species. The life span of coastal shrimp species reported was below 3 years from Indian waters (Dineshbabu and Joseph, 2007; Pillai *et al.*, 2012; Pillai and Thirumilu, 2013).The life span of the deep-sea pandalid shrimp *H. woodmasoni* is reported as 3.66 years for male and 5 years for female from the same location (Radhika *et al*., 2011). Growth of males and females were faster in the first two years compared to successive years. Males grow to a length of 72.6 mm at the end of first year and 105.3 mm at the end of second year with an increment of 32.7 mm. By the end of third year though the shrimp grows to a length of 122 mm, the increment gets reduced to 16.7 mm. Similarly at the end of fourth year the growth rate is further reduced with an increment of 8.4 mm and length of 130.4 mm. Same trend was also observed in case of female when it grows faster in the early ages and then the growth rate reduced considerably. It measured about 63.2 mm, 96.4 mm, 116.1 mm, 127.8 mm, and 134.8 mm with reduced increment of 33.2 mm, 19.7 mm, 11.7 mm and 7 mm at the end of first, second, third, fourth and fifth year respectively.

Age at zero length (t_0) estimated for males, females and combined sex were -0.0858, -0.1002 and -0.0926 respectively. Negative t_o value indicate faster growth rate of fish in their juvenile stage (Ford, 1933; Walford, 1946). Growth Performance Index indicate that the males (Φ = 2.72) have faster growth rates than females (Φ = 2.66). The growth performance index of *P. quasigrandis* falls within the values calculated for other species of *Plesionika* (Garcia *et al.*, 2000, Maiorano *et al*., 2002 and Cengiz *et al.*, 2012). According to Pauly and Munro (1984), related species shows similar values of Growth Performance Index.

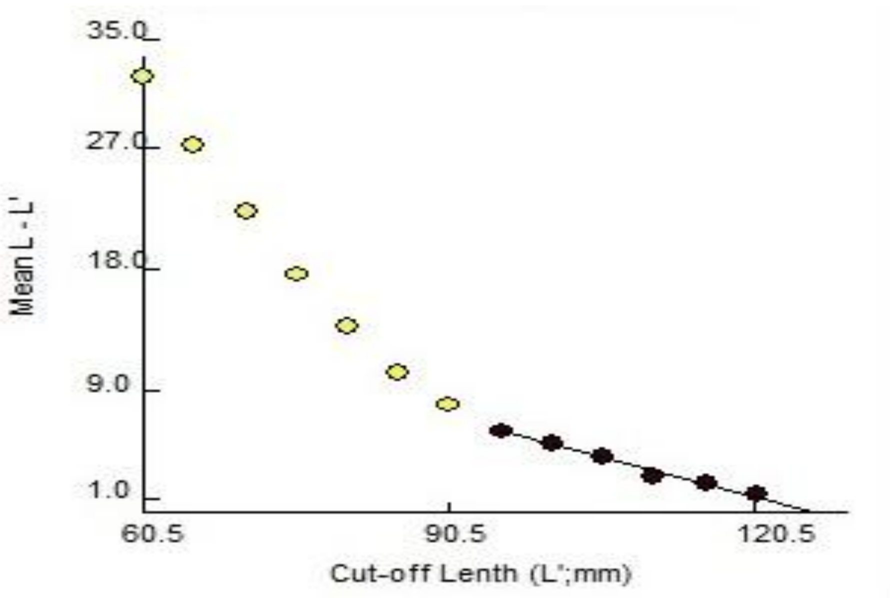


Figure 8.2. Powell-Wetherall plot for estimation of L_∞ and Z/K for *Plesionika quasigrandis* (male)

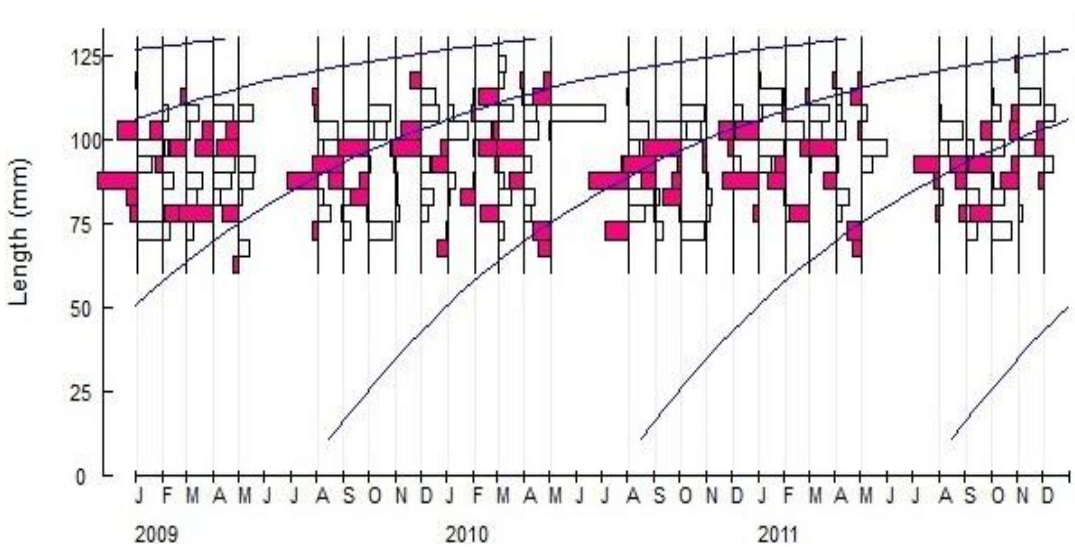


Figure 8.3. Growth curve for *Plesionika quasigrandis* (male) employing ELEFAN

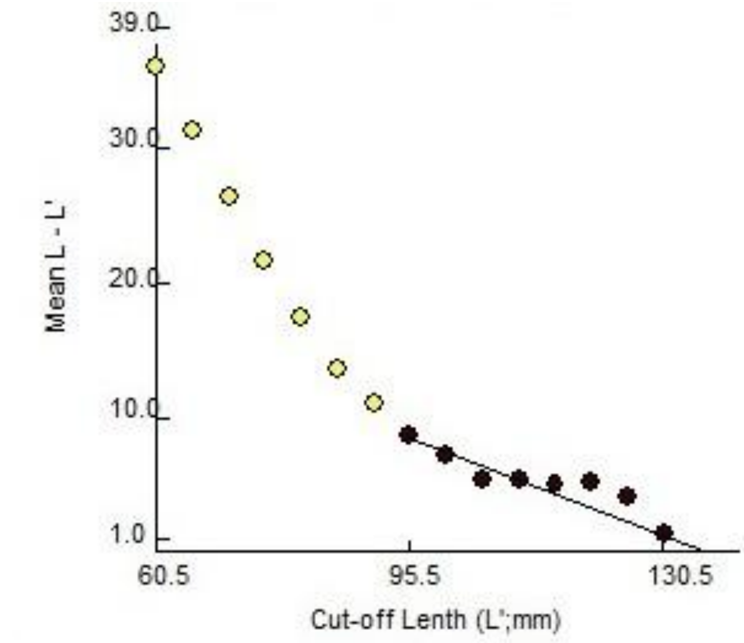


Figure 8.4. Powell-Wetherall plot for estimation of L_{∞} and Z/K for *Plesionika quasigrandis* (female)

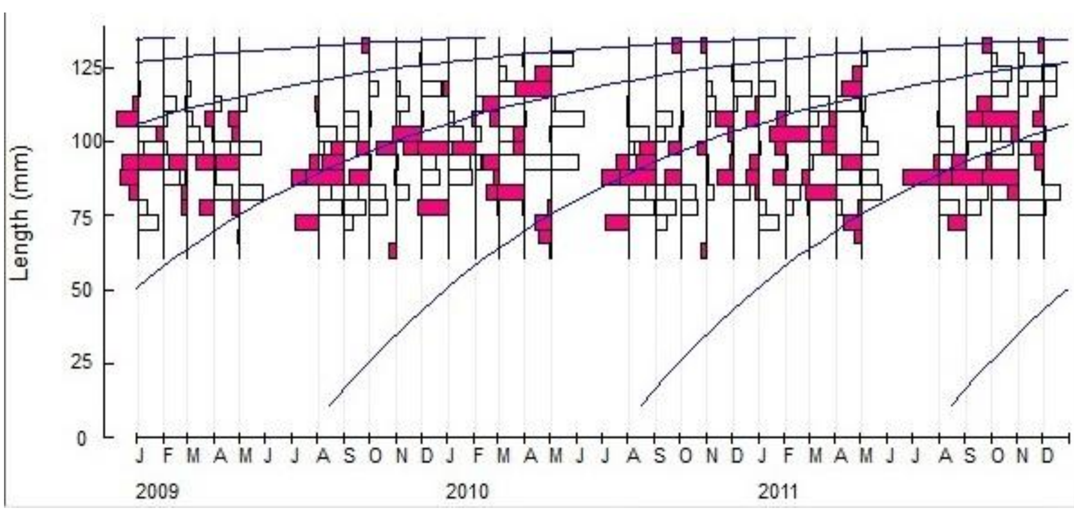


Figure 8.5. Growth curve for *Plesionika quasigrandis* (female) employing ELEFAN

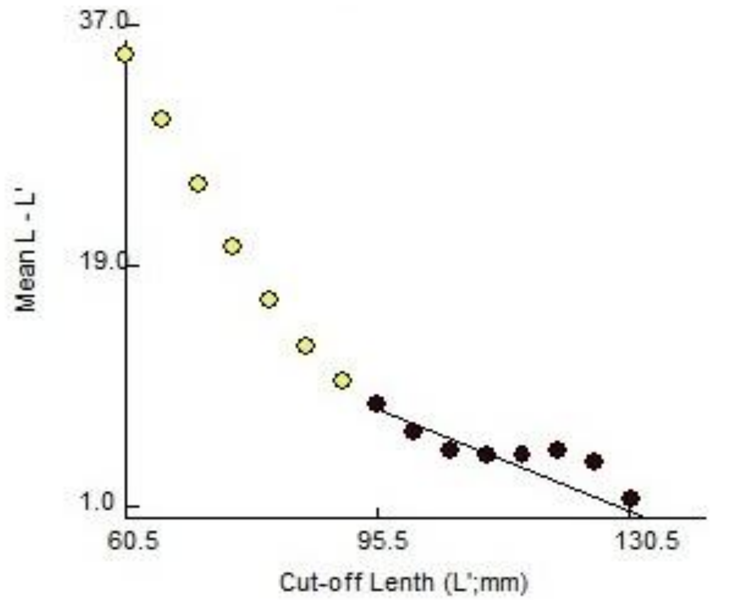


Figure 8.6. Powell-Wetherall plot for estimation of L_∞ and Z/K for *Plesionika quasigrandis* (combined sex)

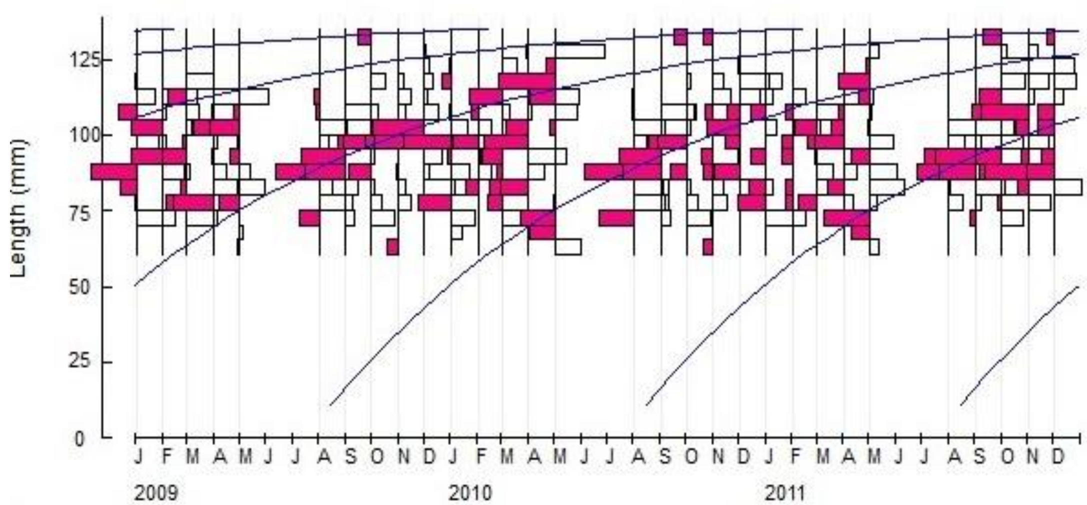


Figure 8.7. Growth curve for *Plesionika quasigrandis* (combined sex) employing ELEFAN

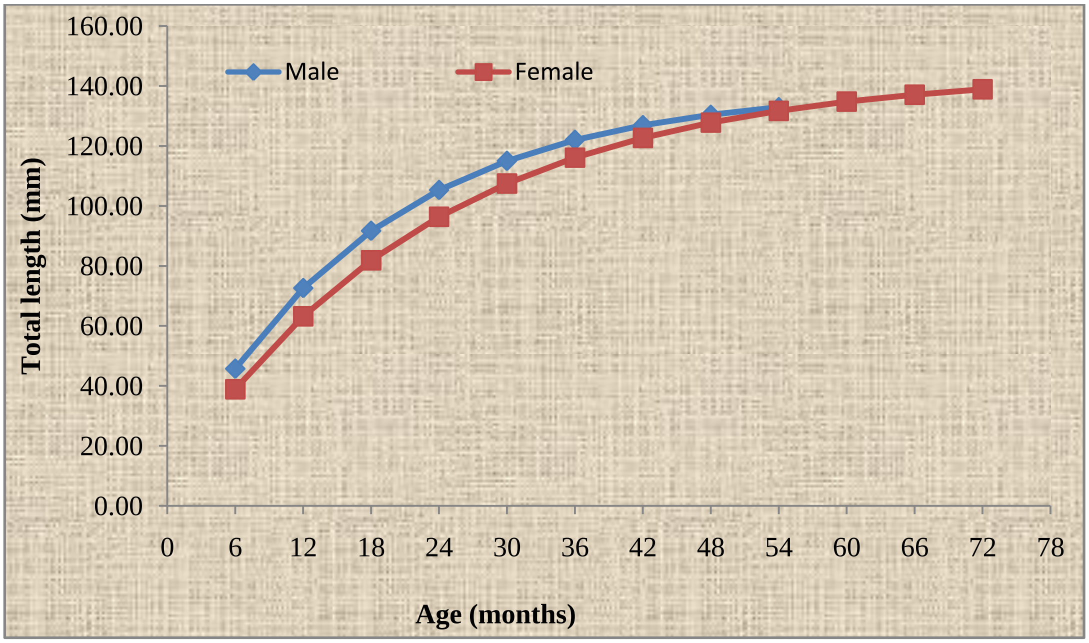


Figure 8.8 Average length attained by *Plesionika quasigrandis* at different ages (months)

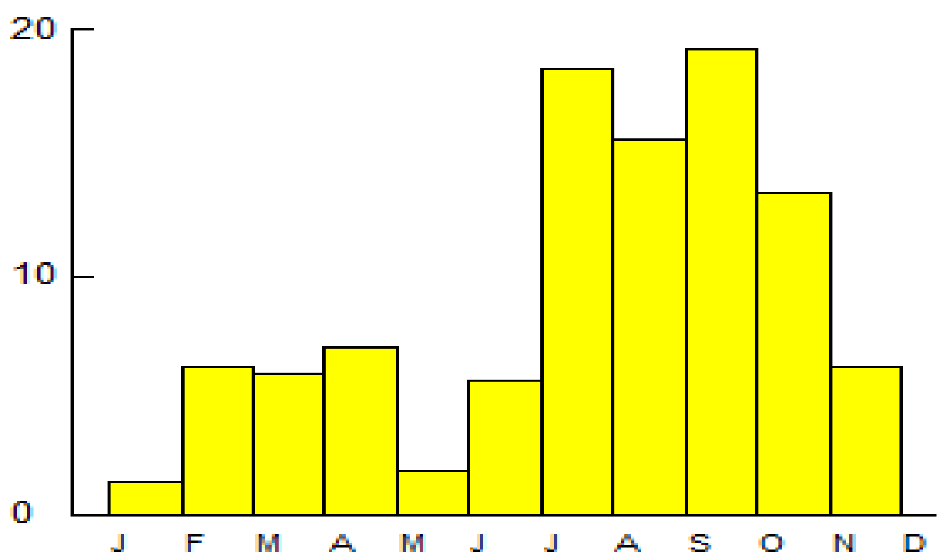


Figure 8.9 Average annual recruitment pattern of *Plesionika quasigrandis*

Chapter 9

Stock assessment

9.1 Introduction

The objective of fish stock assessment is to determine the health status of any stock and to provide scientific advice of their sustainable fishery management. Fishery resources are renewable but their stock status depends upon several factors. Fishery dependent factors like exploitation rate, fishing season and size at capture can be managed to ensure the health of the stock. Sound knowledge on the status of stock helps the researchers and fishery managers to predict yield and the effort required for the sustainable exploitation of the resources. Direct estimation of age or obtaining age-frequency data is difficult in the case of shrimps, so the population parameters are usually estimated using the length frequency data.

The mortality parameters and stock assessment studies on deep-sea shrimps from Indian waters are limited to two species, *Heterocarpus gibbosus* and *H.woodmasoni* (Radhika, 2004). Dailey and Ralston (1986) illustrated stock characteristics of the deep-sea pandalid shrimp, *H. laevigatus* in Hawaii waters. Mortality and yield-per-recruit of deep-sea royal red shrimp *Haliporoides sibogae* was estimated by Baelde (1994) using commercial catch and effort data in Australian waters. Population characteristics of deep-sea pandalid shrimp species were estimated from western Mediterranean Sea (Company and Sarda, 1997) and from northern Aegean Sea (Vafidis *et al.*, 2008). Donghia *et al.* (1998) have given account on the population dynamics of deep-sea aristaeid *Aristaeomorpha foliacea* from northwestern Ionian Sea. Onghia *et al.* (2005) and Beatriz *et al.* (2008) studied the population structure of deep-sea red shrimp *Aristeus antennatus* in the Mediterranean Sea and in the Balearic waters respectively. Olivera and Slobodan (2010) described the stock status and potential yield of deep-sea penaeid shrimp *Parapenaeus longirostris* in Montenegrin waters. Sankare Yacouba *et al.* (2014) studied the growth, mortality rates and yield-per-recruit analysis of exploited deep-sea rose shrimp *P. longirostris* in Ivorian marine waters, West Africa. Similar studies are also available on *Plesionika narval* (Gonzalez *et al*., 1997,) *P. edwardsii* (Santana *et al.*, 1997), *P. antigai* (Campisi *et al.*, 1998), *P. martia* (Maiorano *et al.*, 2002; Chilari *et al*., 2005; Cengiz *et al*., 2012) and *P. semilaevis* (Nakahata *et al.*, 2008).

The present study is the first attempt to understand population characteristics of the deep-sea pandalid shrimp, *P. quasigrandis* and to assess the status of these resources off Kerala coast.

9.2 Materials and Methods

The field data collection procedures in the study were described in the chapter 3 and chapter 8. The growth parameters estimated for pooled sex by ELEFAN method (L_∞=143 mm and K= 0.61 yr^{-1}.) were used for the stock assessment studies (Chapter 8).

Estimation of mortality rate

In any dynamic exploited population, two types of mortality are in operation *i.e.*, natural and fishing mortality. Natural mortality is the mortality occurred by all causes other than fishing (Predation, cannibalism, disease, spawning stress, and old age). Same species may have different natural mortality rates in different locality and region dependent on the density of predators and competitors whose abundance is influenced by fishing activities. Fishing mortality is the significant parameter that should be known in order to assess the impact of fishing on the exploited stock.

Total mortality rate (Z)

Total mortality is the sum total of all mortality in a population. It was calculated by Pauly's (1983) length converted catch curve method and Jones and van Zalinge's (1981) cumulative catch curve method in the FiSAT software.

Length converted catch curve method

This method is also called the "linearized length-converted catch curve method". In this method length data is converted to age data, using the inverse of Von Bertalanffy growth equation. The equation is as follows

$$\ln (N/\Delta t) = a + bt$$

Where Δt is the time taken to grow from lower limit to upper limit in each length class

N= Numbers caught in each length class

a= The Y-axis intercept

b= Z with sign changed

t = Age at a given length

Jones and van Zalinge's method

This method is a variant of length converted catch curve method with a different assumption. Inverse version of von Bertalanffy equation was used along with catch curve method. Cumulated catch curve was converted in to a length based analysis by inserting inverse equation of von Bertalanffy as follows

$$\ln (C(L, L_\infty)) = a + (Z/K) * \ln (L - L_\infty)$$

Where, $\ln (C(L, L_\infty))$= cumulated catch of fish of length L and longer

Regression coefficient b = Z/K, Z= b*K

By regression analysis values of "a" and "b" can be calculated and an estimate of "Z" can be obtained.

Natural Mortality rate (M)

The natural mortality coefficient was calculated by Pauly's empirical method (Pauly, 1980) and Srinath's method (Srinath, 1998).

Pauly's empirical method

Pauly (1980) made a multiple regression analysis to calculate natural mortality (M) the following formula given below

$\ln M = -0.0152 - 0.279 * \ln(L_{\infty}) + 0.6543 * \ln(K) + 0.4634 \ln(T)$

Srinath's formula (1998)

Natural mortality (M) was calculated following the formula given below

$M = 1.68 * K$

Fishing Mortality rate (F)

Value of fishing mortality (F) was derived from Z and M.

F= Total mortality rate (Z) –Natural mortality rate (M)

Exploitation Rate (E) and Exploitation ratio (U)

Exploitation Rate (E) refers to the ratio of mortality due to fishing to total mortality (Ricker, 1975). It is calculated by the following equation.

E = Fishing mortality rate (F) / Total mortality rate (Z)

Exploitation ratio (U) is defined as the fraction of fish present at the start of a year that is caught during the year. It is computed by the equation given by Beverton and Holt (1957) and Ricker (1975).

$$U = F/Z\,(1-e^{-z})$$

Yield and Stock

Yield is the fraction of fish population in weight taken by the fishery and is denoted by Y. Standing stock is a concentration of fish population for a given area at a given time. It is calculated from the equation,

Standing stock = Yield (Y)/Fishing mortality rate (F)

Total stock or biomass refers to the total weight or number of fish population available for a given area at a particular time. It is estimated from the relation,

Total stock = Yield (Y)/ Exploitation ratio (U)

Probability of capture

Complete length range of targeted population is not always under full exploitation and the selectivity is determined by the cod end mesh size in trawl nets. The mean length (L_{50}) at which a fish has 50% chance of being retained by the net is estimated for suggesting the regulatory measures of the gear. The probability of capture of the shrimp was estimated using logistic curve method in the FiSAT II software.

Optimum length of exploitation (L_{opt})

Optimum length of exploitation was estimated empirically from the equation (Froese and Binohlan, 2000) as,

$L_{opt} = 3*L\infty/ 3+M/K$

Where, $L\infty$ is asymptotic length, M is natural mortality rate and K is growth coefficient

Relative yield per recruit (Y/R) and biomass per recruit (B/R) analysis

Beverton and Holt (1966) proposed relative yield-per-recruit (Y'/R) based on the concept that what matters is the relative difference of Y/R for different values of F. The model is suitable for assessing the effect of mesh size regulations. The Y'/R and B'/R were obtained from the estimated growth parameters and probabilities of capture by length (Pauly and Soriano, 1986). The estimates were made using FiSAT II (Knife-edge selection).

The relative yield per recruit calculated by

$$(Y/R)' = E * U^{M/K} * \left[1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{3U^3}{1+3m}\right]$$

$$\text{Where } m = \frac{1-E}{M/K} = \frac{K}{Z}, \quad U = 1-(Lc/L\infty), \; E = F/Z$$

Relative biomass-per-recruit (B'/R) is calculated from the relationship,

B'/R = Yield per recruit (Y'/R)/ Fishing mortality rate (F)

Maximum Sustainable Yield

Maximum sustainable yield (MSY) is a measure of fish stocks that can be sustainably exploited from an ecosystem. This refers to the weight of fish that can be taken by fishing without reducing the stock's biomass on a continuing basis. Many factors contribute to the determination of MSY for a species. These include growth rate, reproduction pattern, how fast they grow and the harvesting strategies. The MSY for a fish stock is also changeable over time, because of variations in productivity and environmental factors. The MSY was calculated by the formula of Gulland (1965) as

MSY= Z(Y/F)*0.5

Where, Z is total mortality coefficient, Y is yield and F is fishing mortality rate.

The MSY was also calculated following the length based Thompson and Bell model

Virtual Population Analysis (VPA)

Length structured virtual population analysis (Pauly, 1984) is a modified version of Jones and van Zalinge (1981). It is also called cohort analysis because each cohort is analysed independently. Here length frequency, $L\infty$ and K are used as input parameter. This provides information on natural mortality, fishing mortality and survivors in each length group. Here it is assumed that all length classes caught during one year reflects that of a single cohort during its entire life span. The estimates were made using FiSAT II software.

Thompson and Bell model

Thompson and Bell model is a very important tool to predict catches and stock size under given assumption on future exploitation levels, fishing effort, closed season and mesh size. A significant feature of the Thompson and Bell model is that it allows for the incorporation of the cost of the catch. Hence, the model has become the basis for the development of the so-called bio-economic models, which are very useful for the predictions needed for management decisions. The length based Thompson and Bell model (Sparre and Venema, 1993) use inputs from length based cohort analysis. This include fishing mortalities by length group, the growth parameter K and the natural mortality factor by length group, the same as used in the cohort analysis. The outputs are for each length group the number at the lower limit of the length group N (L_1), catch in numbers, yield in weight**,** biomass multiplied by t, i.e., the time required to grow from the lower limit to the upper limit of the length group. Thompson and Bell analysis provide average long term catches assuming recruitment to remain constant. FiSAT II software was used for this analysis.

9.3 Results

9.3.1 Mortality coefficients

Total mortality coefficient (Z) of *P. quasigrandis* estimated by various methods provided in the Table 9.1 and the length converted catch curve and the Jones van Zalinge plot are presented in Fig. 9.1 and Fig 9.2. Estimated values of Z by length converted catch curve method were 3.26, 2.94, 2.77 for 2009, 2010, 2011 respectively and 2.85 for the entire period.

Table 9.1. Estimates of total mortality coefficient (Z) derived by different methods

Method	2009	2010	2011	2009–11
Catch curve method	3.26	2.94	2.77	2.85
Jones and van Zalinge	3.74	3.45	3.4	3.31
Beverton and Holt model	3.1	2.82	2.71	2.78
Ault and Ehrhardt method	3.29	2.77	2.76	2.81

Natural mortality coefficient (M) calculated was 0.65 and 1.02 by Pauly's empirical formula and Srinaths's formula respectively. Fishing mortality coefficient computed as 2.61, 2.29, and 2.12 for 2009, 2010, 2011 and mean for the entire period as 2.2.

9.3.2 Exploitation Rate (E) and exploitation ratio (U)

Estimates of exploitation rate E was 0.80, 0.78, 0.77 and 0.77 for the years 2009, 2010, 2011 and the pooled years respectively. The exploitation ratio (U) for the same period was 0.77, 0.75, 0.73 and 0.74.

9.3.3 Probability of capture

The result of length-converted catch curve analysis was used as input data for estimating probability of capture. Size at capture of *P.quasigrandis* for pooled sex were L_{25}= 83.16 mm, L_{50}= 86.34 mm and L_{75}= 89.52 mm (Fig.9.3). Length at first capture (L_{50}) was taken as inputs in the Beverton and Holt relative yield and biomass per recruit analysis and Thompson and Bell yield prediction analysis. The optimum length (L_{opt}) estimated empirically was 93.7 mm. Estimated L_{opt}/L_{∞} value was 0.65.

9.3.4 Virtual Population Analysis

Virtual population analysis (VPA) provides number of survivors and mortality in each cohort for the respective period. The results of length based virtual population analysis indicated that the middle length groups (91–120 mm) experience higher fishing mortalities with maximum values for the length group of 106–110 mm (Table 9.2 and Fig.9.4).

Table 9.2. Results of Length structured VPA for *Plesionika quasigrandis* during the period 2009–2011

Length group (mm)	Mid point	Catch in N (^0000)	population in N (^0000)	Fishing mortality	Steady state biomass (t)
61–65	63	1402	974649	0.0145	2286
66–70	68	2127	910477	0.0222	2967
71–75	73	5478	845968	0.0576	3768
76–80	78	26703	778671	0.2882	4628
81–85	83	40580	691746	0.4626	5445
86–90	88	69234	594150	0.8735	6037
91–95	93	90672	473395	1.3717	6108
96–100	98	75111	339756	1.4607	5707
101–105	103	70166	231220	1.8993	4880
106–110	108	57517	137041	2.5417	3528
111–115	113	26441	64815	2.1272	2270
116–120	118	11279	30295	1.6023	1496
121–125	123	3777	14440	0.8512	1090
126–130	128	1452	7780	0.4516	908
131–135	133	1842	4237	0.5	1190

The value of F is higher than 2 for the size class of 106–110 mm (F= 2.54) and of 111–115 mm (F=2.12). The mean numbers, in each length group showed that catch dominated by 91–95 mm length group. The yield increased from the size class 76–80 mm to the maximum in the size class 91– 95 mm and then gradually reduced. The results indicated that species up to 71–75 mm length group were succumbed mainly to natural causes whereas from 76–80 mm onwards, they become more vulnerable to the gear due to fishing mortality exceeded natural mortality.

Table 9.3. Relative yield per recruit and biomass per recruit for *Plesionika quasigrandis* during the period 2009–2011

Exploitation rate (E)	Relative yield per recruit (Y'/R)	Relative biomass per recruit (B'/R)
0.05	0.0098	0.285
0.1	0.0191	0.2644
0.15	0.028	0.2442
0.2	0.0365	0.2244
0.25	0.0444	0.2051
0.3	0.0519	0.1862
0.35	0.0588	0.1679
0.4	0.0651	0.1501
0.45	0.0707	0.133
0.5	0.0757	0.1165
0.55	0.08	0.1007
0.6	0.0835	0.0857
0.65	0.0862	0.0714
0.7	0.0881	0.0581
0.75	0.0891	0.0457
0.8	0.0892	0.0343
0.85	0.0884	0.024
0.9	0.0868	0.0148
0.95	0.0843	0.0068
1	0.081	0

9.3.5 Relative yield per recruit and biomass per recruit (Y'/R and B/R)

The relative yield-per-recruit (Y'/R) and biomass-per-recruit (B'/R) were determined as a function of L_{50}/L_∞ and M/K. The input data for the knife-edge selection was L_c/L_∞ (0.60) and M/K (1.07). The result of analysis was presented in the Table 9.3 and Fig. 9.5. As per Y'/R curve maximum yield per recruit E_{max} is 0.79. The current exploitation rates (E) of 0.77 for the period 2009–11is below the predicted E_{max} value.

Table 9.4. Yield, Biomass and revenue from different levels of fishing

Factor-X	Yield (t)	Biomass (t)	Value ('000)
0	0	10069	0
0.2	1457	6436	55598
0.4	2069	4568	75756
0.6	2324	3527	81966
0.8	2423	2901	82585
1	2452	2498	81020
1.2	2448	2221	78694
1.4	2430	2020	76199
1.6	2407	1866	73776
1.8	2382	1745	71514
2	2357	1646	69432
2.2	2332	1563	67527
2.4	2310	1493	65785
2.6	2288	1432	64188
2.8	2268	1379	62720
3	2249	1332	61366

9.3.6 Biomass and Maximum sustainable yield

The total yield of *P.quasigrandis* was 2424 t, 1819 t and 2692 t respectively for 2009, 2010 and 2011 and the average yield for the period was 2312 t. The estimated total stock was 3147 t in 2009, 2426 t in 2010 and 3670 t in 2011 with

3125 t in mean for the period and respective standing stock was 925 t, 791 t, 1270 t and 1051 t.

The results of the Thompson and Bell analysis is given in Table 6.4 and Fig. 9.6. The 'F' factor of 1.0 indicates the present level of fishing with 2498 t and 2452 t biomass and yield respectively. The analysis showed that the present level of fishing near to the maximum sustainable yield. At the present level of fishing the biomass has declined to 2498 t as compared to the virgin biomass. The size-wise average market rate of the species used for the estimation of maximum economic yield (MEY). The MEY is obtained at F-factor of 0.8. Net revenue generation form the fishery showed a decline from the F-factor of 1. Maximum sustainable yield (MSY) estimated was 1497 t by Gulland's method and by using length-based Thompson and Bell prediction model is 2452 t.

Table 9.5. Selected population parameters of *Plesionika quasigrandis* during the period 2009–11

Population parameters	Values
Total mortality (Z)	2.85
Natural mortality (M)	0.65
Fishing mortality (F)	2.21
L_c in mm	86.34
L_c / L_∞	0.6
M/K	1.07
L_{opt}/L_∞	0.655
Length at maximum possible yield (L_{opt}) in mm	93.7
Exploitation rate (E)	0.77
Exploitation ratio (U)	0.74
Maximum at exploitation rate (E_{max})	0.79

9.4 Discussion

The growth is constructive part in the dynamics of a population, while its counterpart is mortality. Information on different mortalities operating in a population is essential for proper understanding of their dynamics, which gives indication on how fast individuals are removed from the population by different causes like natural death or fishing. Natural mortality is influenced by several biological and environmental factors and it is difficult to get an accurate estimate (Pauly, 1980). It is related to growth parameters like L_∞ (Sparre and Venema, 1993) and maturity (Rikhter and Efanov, 1976). The empirical equation of Pauly (1980) and method described by Srinath (1998) were used to derive natural mortality in the present study. The M value estimated by Pauly's empirical formula (0.65) was lower than Srinaths's method (1.02). Pauly's empirical formula based on interrelationship between growth parameters and mean habitat temperature and considered as more reliable. So value calculated by Pauly's empirical formula was used for subsequent studies. Beverton and Holt (1957) pointed out that the natural mortality coefficient of a species is directly related to the growth coefficient (K) and inversely related to the asymptotic length (L_∞) and life span. Accordingly *P. quasigrandis* which have lower growth coefficient of 0.61 yr^{-1} and higher lifespan of 4.9 years was found to have relatively lower natural mortality coefficient of 0.65 yr^{-1}. The reliability of natural mortality is determined by the M/K ratio, the ratio lies within the range of 1–2.5 for most species and has been found to be similar for closely related species and sometimes for similar taxonomic groups (Beverton and Holt, 1959; Banerjee, 1973). In the present study the M/K ratio was 1.07 which is within the range and hence suggests that the natural mortality calculated for *P.*

quasigrandis is reliable and value is close to M/K ratio (0.95) reported in the deep-sea pandalid shrimp *H. woodmasoni* from Kerala waters (Radhika *et al.*, 2011).

Total mortality coefficient (Z) values by Jones and van Zalinge's method were higher than obtained from catch curve method and smaller than that by Beverton and Holt model. Value obtained by catch curve method was used for further studies as this provided the facility to proceed to the estimation of probability of capture and this method is based on more input parameters. Total mortality coefficient obtained in the year 2009 (3.26) was high when compared to the successive years 2010 (2.94) and 2011 (2.77). As a rule the Z/K ratio of 1.0 is considered as growth dominated and if it is more than 2, then it is mortality dominated. In the present study, it was more than 4, which showed that the stock of *P. quasigrandis* was mortality dominated. Estimated fishing mortality rates were larger than natural mortality rates which account to 77.19% of total mortality.

Length at first capture (L_{50}) was 86.34 mm and the age at first capture was (t_{50}) calculated as 1.4 years. Optimum length of exploitation (L_{opt}) estimated as 93.7 mm against the present length at first capture (L_{50}) 86.34 mm suggesting that the length at first capture need to be increased. Virtual population analysis indicates that fishing mortality for this species have shown high value in the middle length groups.

Yield per recruit analysis provide adequate information on exploitation. The study indicated that at $E_{0.1}$ the Y/R is 0.0191g, whereas at $E_{0.5}$, Y/R is 0.0757g and at E 1.0 the Y/R is 0.0810 g at which the biomass reaches at zero. Average biomass exploited was 23% of the initial biomass. At the present exploitation rate the yield/recruit is about 0.0892 g and the biomass is 0.0343g/ recruits. As per yield per recruit curve maximum is obtained at 0.79 (E_{max}) and the present exploitation is 0.77. This indicates that at present the species is exploited very close to the maximum exploitation level. However the Thompson and Bell predictive model also shows that the present level of fishing provides the maximum sustainable yield. The results show that at the current level of fishing the biomass has declined to 2498 t as compared to a virgin biomass of 10069 t. At present the yield is 2452 t which is 78.46% of total stock. Maximum sustainable economic yield (MEY) is at the fishing effort of 0.8 after which the revenue generation shows decline and also further increase in effort gives only a marginal increase in yield.

The deep-sea shrimp *P. quasigrandis* exploited from the present fishing ground and their monetary return has started showing a declining trend. By observing the current yield and economic return, there is no further scope for increasing the catch from the present fishing ground. The study indicated (chapter 3) that majority of the deep-sea shrimp trawlers, especially targeted for pandalid shrimps still concentrated off Kollam area (Quilon Bank). Even though researchers had located several potential deep-sea fishing grounds based on exploratory surveys in Indian EEZ (Venu and Kurup, 2002; Jayaprakash *et al.*, 2006; Kurup *et al.*, 2008; Somvanshi *et al.*, 2009; Ganga *et al.*, 2012; Hashim, 2012), fishermen are unaware of these fishing grounds located and hence sharing the information about new potential deep-sea fishing grounds could avert the possible stock decline due to the intensive targeted deep-sea shrimp fishery in the Quilon Bank. Hence, the present study recommended that part of the effort from existing fishing grounds may be shifted to newly located deep-sea fishing grounds which will help in a sustainable exploitation of deep-sea resources off Kerala coast.

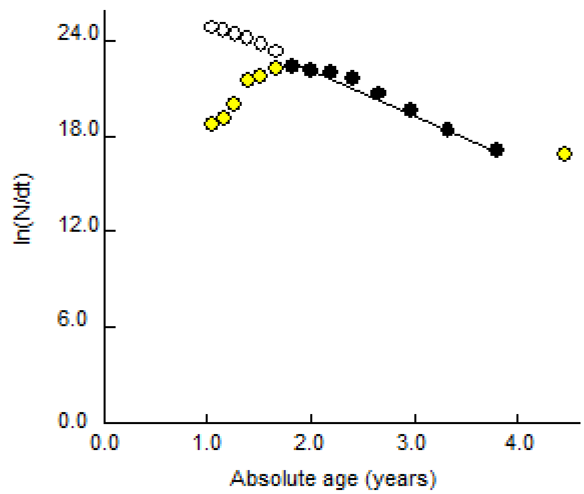


Figure 9.1. Length-converted catch curve of *Plesionika quasigrandis* during the period 2009–11

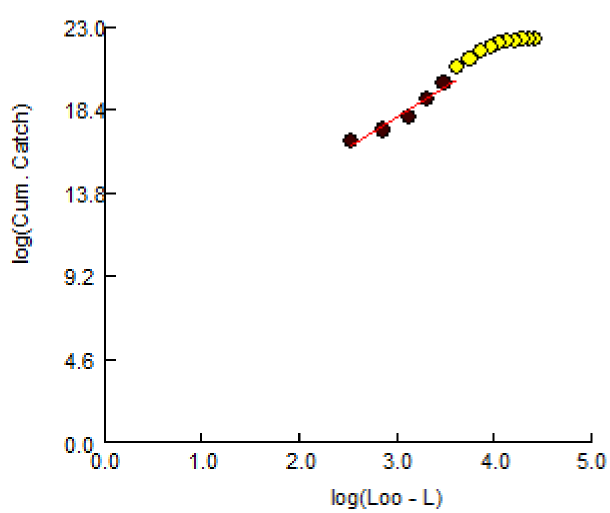


Figure 9.2. Jones and Van Zalinge's cumulative catch curve of *Plesionika quasigrandis* during the period 2009–2011

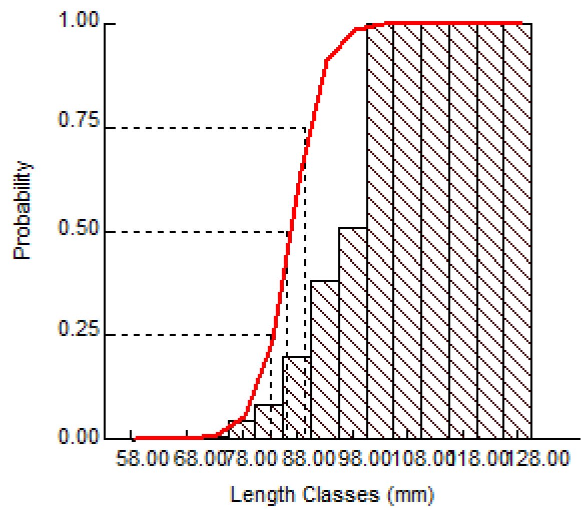


Figure 9.3. Probability capture of *Plesionika quasigrandis* during the period 2009–2011

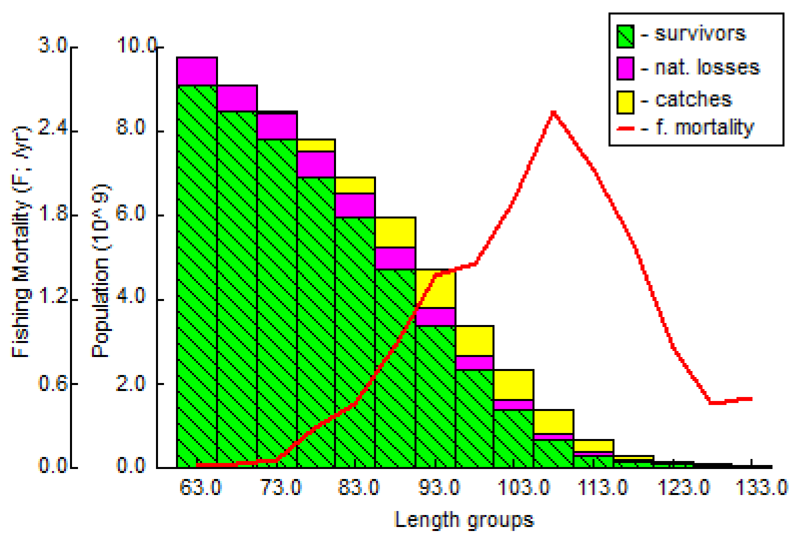


Figure 9.4. Length structured VPA of *Plesionika quasigrandis* during the period 2009–2011

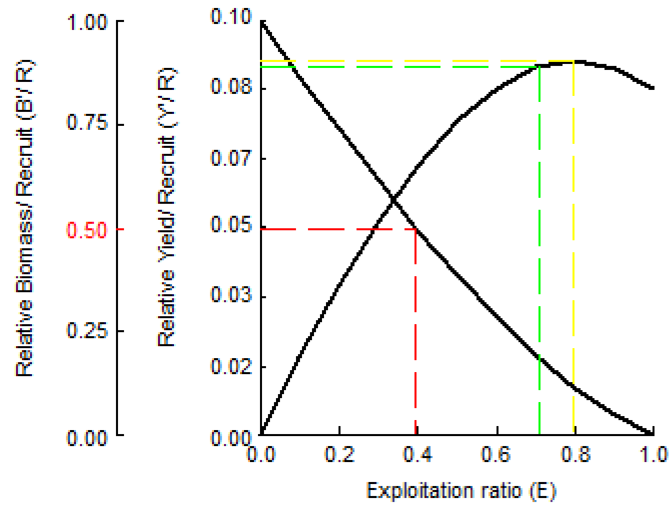


Figure 9.5. Relative yield per recruit and biomass per recruit curve of *Plesionika quasigrandis* during the period 2009– 2011

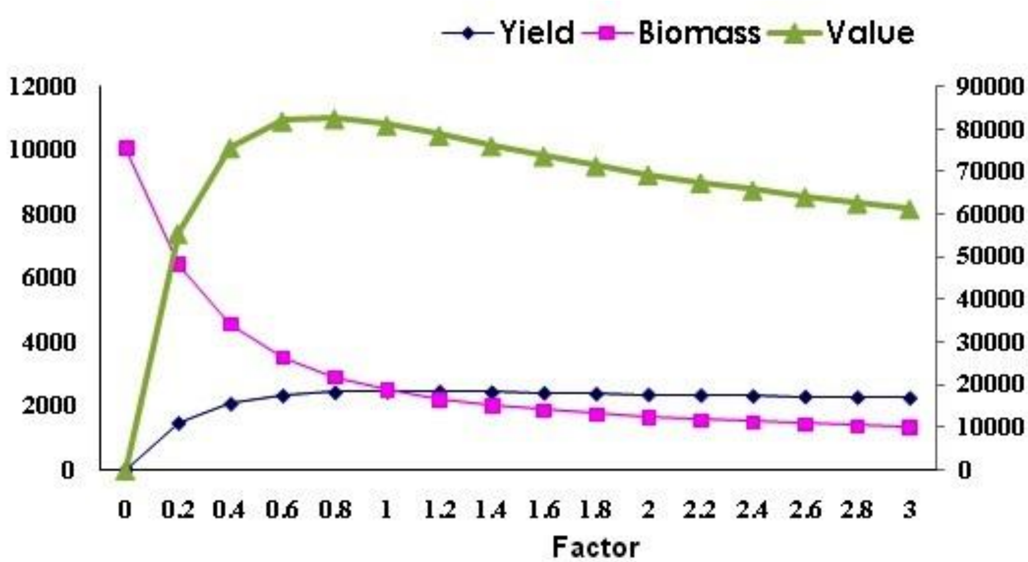


Figure 9.6. Thompson and Bell predictive analysis for *Plesionika quasigrandis* indicating MSY and MEY

SECTION IV

SUMMARY AND RECOMMENDATIONS

Summary

- The data on catch, effort, species composition, samples for taxonomic studies and stock assessment were collected from Sakthikulangara, Vypin and Cochin Fisheries Harbour during the period from January 2009 to December 2011.The samples of *P. quasigrandis* for biological studies (length-weight relationship, reproduction and food and feeding) were collected from above mentioned centers during January 2010 to December 2011
- Decapod crustaceans landed by deep-sea shrimp trawlers during the study period consisted of 26 species, belonging to 17 families. Shrimps were the most diverse group with nineteen species recorded followed by lobsters (3), crabs (2) and squat lobsters (2).
- Based on examination of morphological characters and colour pattern of specimens collected during the study, it is confirmed that the species occurring in Indian waters is *P. quasigrandis* and not *P. spinipes*.
- Stylodactylid shrimp *Parastylodactylus sulcatus* is new deep-sea shrimp, described from Arabian Sea during the present study is the first representative of the family Stylodactylidae from Indian waters.
- Reef lobster *Enoplometopus macrodontus* and pandalid shrimp *Plesionika adensameri* were recorded for the first time from Indian waters.
- Two types of deep-sea shrimp trawling operations exist along the Kerala coast based on the targeted shrimp species group. One for ‘red ring’ (*Aristeus alcocki*), for which fishing operation are normally conducted at greater depths

(> 350 m) and others targets deep-sea shrimps which primarily constitutes pandalid shrimps and operate at a depth ranging between 190–350 m.

- Among the nineteen species of deep-sea shrimps observed in the landings, only seven species were dominant such as *Aristeus alcocki*, *Heterocarpus gibbosus*, *H. woodmasoni*, *Metapenaeopsis andamanensis*, *Plesionika quasigrandis*, *P. martia* and *Solenocera hextii*.
- Total landings of deep-sea shrimps in Kerala were estimated 8579 t, 7082 t and 10490 t during the years 2009, 2010 and 2011 respectively.
- Annual average catch rate of 'red ring' was 26.8 kg/hr, 26.3 kg/hr and 28.2 kg/hr during 2009, 2010 and 2011 respectively. But in the case of other deep-sea shrimps the catch rate observed was comparatively low and recorded as 22.6 kg/hr, 20.9 kg /hr and 20.3 kg/hr in the respective years. The average catch rate of total deep-sea shrimps during the period was 24.19 kg/hr.
- During 2009, the maximum and minimum landing was observed in November and August respectively. During 2010 and 2011, a similar trend was observed with highest catch recorded in November and December and a minimum catch in May of the respective years. Lowest landings were recorded during August and May in all years of the study period.
- Pandalid shrimps were the dominant group in the fishery, representing nearly 54.7% of the total landings.
- Pandalid shrimp *P. quasigrandis* was the dominant species in the fishery and contributed to 28.3%, 25.8%, 25.7% of the total landings during 2009, 2010 and 2011 respectively.
- 'Red ring' is the most valued species among the deep-sea shrimps and majority

of the fishermen started selective harvesting of this species. As a result landing of ‘red ring’s increased, contributing to 18.8%, 21.2% and 24.7% of total landings during 2009, 2010 and 2011 respectively.

- Along the Kerala coast, deep-sea shrimp landings were observed only in three harbours, namely Sakthikulangara, Vypin and Cochin Fisheries Harbour and 68% of the catch was landed at Sakthikulangara Fisheries Harbour.
- Cochin Fisheries Harbour accounted for the major share of the ‘red ring’ catch and formed more than 38% of the total deep-sea shrimp landings in this harbour during 2009–11. Pandalid shrimp *P.quasigrandis* was the dominant species in Sakthikulangara (27%) and Vypin (29%).
- Average capital investment for shrimp trawlers worked out to be Rs.42.85 lakhs and 79% of trawlers in the deep-sea shrimp fishery were under shared ownership.
- Average operational cost per trip was estimated as Rs. 2.11 lakhs for ‘red ring’ and Rs.1.47 lakhs for other shrimp. The operational cost of trawlers targeting ‘red ring’ was found high on account of day-night fishing operation, duration of fishing trips and distance of fishing ground.
- Total operational cost indicated that the cost of fuel was the major component contributing around 55% of the total cost and followed by crew share (22%).
- Average revenue per trip has been estimated at Rs. 3.03 lakhs for ‘red ring’ and Rs. 2.02 lakhs for other deep-sea shrimps.
- Operating ratio was worked out to be 0.69 and 0.72 for trawlers targeting ‘red ring’ and other deep-sea shrimps respectively, indicating that 69% and 72% of the net revenue generated was spent for operational expenses.

- Rate of return, profitability ratio and the net profit ratio for the 'red ring' is estimated to be 0.35, 0.38 and 0.26 respectively while for the other deep-sea shrimps it was found to be 0.28, 0.29 and 0.21.
- High operational cost, high risk and effort, lack of trained and skilled crew, low market price realisation, abundance of discards, poor quality of shrimps and low level of technology were the major problems encountered in the deep-sea shrimp fishing operations.
- Highest score of 81.43, is for the high operational cost followed by the score of 80.95 for the low market price of deep-sea shrimps and the lowest score (17.14) for low level of technology.
- The 'b' value for total length-weight and carapace length-weight relationship of *P. quasigrandis* for males, ovigerous females and non-ovigerous females indicated allometric growth.
- Overall sex ratio of *P. quasigrandis* was 1:1.4 in favour of females which was significantly different from the expected sex ratio.
- Three stages of egg development were identified according to morphological examination and colour.
- Mean length at first maturity for females was 84 mm total length. Size at onset of sexual maturity for male was 77 mm and female was 79 mm.
- Overall fecundity varied from 1461 to 7189 eggs with an average of 5196 eggs.
- Reproductive output (RO) varied between 0.07–0.13 and the egg weight comprised on average 9.9% of the body weight of female with early developmental stage.
- High percentage of ovigerous females was observed during the month of

November in 2010 (73.4%) and December in 2011 (71.6%). The overall percentage of berried females was 63.47% during 2010 and 61.16% during 2011.

- Index of Preponderance indicates that detritus contributed a significant part of stomach contents of male (42.70) and non-ovigerous females (41.17), whereas in the ovigerous females it contributed with an index of 30.38.
- Crustacean remains (Index 21.22) were the second important prey item among the stomach content.
- Annual feeding condition showed high percentage of empty stomachs and the proportion was 46.02%. Percentage of full stomach was comparatively low in case of non-ovigerous females (3.5%) than the ovigerous females (4.47%) and males (5.54%).
- Modal size group of males in the fishery was 96–100 mm during the year 2009 and 2010, but in 2011 it was 91–95 mm. In the case of females the modal size group was 90–95 mm, 96–100 mm and 86–90 mm during the year 2009, 2010, and 2011 respectively.
- Growth parameters estimated for male *P. quasigrandis* were $L\infty$ =139 mm, K =0.68 yr^{-1}, t_0=0.0858.
- Growth parameters estimated for female *P. quasigrandis* were $L\infty$ =145 mm, K =0.52 yr^{-1}, t_0= -0.1002.
- Growth performance index was 2.72, 2.66 and 2.70 for males, females and combined sex respectively.
- Longevity of males and females were estimated at 4.4 years and 5.8 years respectively.

- Natural mortality coefficient (M), total mortality coefficient (Z) and fishing mortality coefficient (F) during 2009–11 were estimated as 0.65, 2.85 and 2.2 respectively.
- Exploitation rate (E) was estimated as 0.77 and exploitation ratio (U) as 0.74. The length at first capture ($_{L50}$) was 86.34 mm and the age at first capture ($_{t50}$) was calculated as 1.4 years. The optimum length of exploitation ($_{Lopt}$) estimated as 93.7 mm against the present length at first capture ($_{Lc}$) 86.34 mm indicates that length at first capture needs to be increased.
- Virtual population analysis indicates that the fishing mortality for this species have shown high value in the middle length groups (91–120 mm).
- At the present level of exploitation rate the yield/recruit is about 0.0892 g and the biomass is 0.0343g/ recruits. As per the yield per recruit curve, (E_{max}) was 0.79 and on the basis the present exploitation rate of 0.77, it could be seems that the species is exploited very close to the maximum exploitation level. Thompson and Bell predictive model also shows that the present level of fishing provides the maximum sustainable yield. The maximum sustainable economic yield (MEY) is at the fishing effort of 0.8 after which the revenue generation shows a decline and also further increase in effort gives only a marginal increase in yield.

Recommendations

- Systematics of deep-sea decapod crustaceans from Indian waters is poorly studied in last few decades. Majority of the deep-sea decapod species were described and reported hundred years back based on the surveys of the RIMS

'*Investigator*'. A major revision of the systematics of deep-sea decapod crustaceans is required incorporating both morphology and molecular studies.

- Deep-sea shrimps are more fragile compared to fishes and most of the deep-sea shrimp samples obtained from trawl net were damaged with broken body appendages, making proper taxonomic identification of many species difficult. Using shrimp traps in exploratory survey vessels may be useful in getting undamaged samples for accurate identification in systematic studies.
- Research institutes have located many new deep-sea fishing grounds based on the deep-sea exploratory surveys, the fishermen are unaware of these new fishing grounds. After accurate estimates of species composition and their turnover rates as well as biomass estimates, the information can be disseminated to fishermen so that the operation could be shifted to newly located deep-sea fishing grounds which will help in reducing fishing pressure on the existing grounds.
- Many deep-sea fishing grounds in Indian EEZ are rich in shrimps and lobsters, however majority of these grounds are not suitable for trawling operations due to uneven and sloping bottoms. Shrimp traps are used in many countries for the exploitation of deep-sea shrimp and lobsters. This study suggests that the introduction of shrimp traps in potential deep-sea fishing grounds of Indian EEZ will help to exploit deep-sea crustacean resources in a sustainable manner.
- Exploratory surveys for new fishing areas should be continued and mapping the potential fishing grounds on a GIS platform will enable proper formulation of policies for deep-sea fisheries exploitation. It will also help in monitoring

such resources on a scientific basis regularly and enable in fixing of quotas/catch regulations whenever required and thereby ensuring optimal utilisation of fishery resources.

- The study indicated availability of large quantities by-catch of finfishes in deep-sea shrimp trawlers, most of them are discarded in sea. Biochemical analysis indicated that many of the deep-sea fishes are with high protein and low fat. Economically viable post-harvest technology and value addition for the by-catch fishes needs to be developed for better profit from this sector and for ensuring nutritional security.
- There exits an increased risk and uncertainty in the deep sea fishing operation. So free insurance coverage for deep-sea shrimp trawlers should be provided. The deep-sea fishing vessels should have proper identification marks and communication equipments. so that the vessels could be monitored using satellite communication systems.
- Most of the deep-sea fishing grounds are across the international shipping channel area and there is no Vessel Traffic Management System (VTMS) exists along the Indian coast. So proper Vessel Traffic Management System should be implemented to ensure the safety of the trawlers.
- Studies on biological aspects of most of deep-sea shrimp species in the fishery are insufficient. Further studies on the biology and population parameters of this resource and associated fishery have to be encouraged for evolving better management options for sustainable exploitation of these resource.
- Specific management regulations should be developed for deep-sea fishery considering the unique biological characteristics of the deep-sea species.

Proper regulations to ensure sustainability of specific high value fishery resources should be in place prior to expansion of deep-sea fishery programs by the Government and other agencies.

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PUBLICATIONS

List of publications

1. **C.P. Rajool Shanis,** K.V. Akhilesh, Hashim Manjebrayakath, U. Ganga & N.G.K. Pillai 2012.Shrimps of the family Pandalidae (Caridea) from Indian waters, with new distributional record of *Plesionika adensameri* (Balss, 1914). *J. Mar. Biol. Ass. India,* 54 (1), 1-8, January-June 2012. (http://eprints.cmfri.org.in).
2. **C.P Rajool Shanis** and Radhakrishnan, E V and Ganga, U and Pillai, N G K (2014) Misidentification in fishery: the case of deep-sea pandalid shrimp *Plesionika spinipes* (Spence Bate, 1888) from Indian waters. International Journal of Marine Science, 4 (50). pp. 1-4. (http://eprints.cmfri.org.in).
3. **C.P Rajool Shanis**, Shyam, S Salim, Hashim Manjebrayakath, U Ganga, Manjusha U and Pillai, N G K (2014*)* Deep-sea shrimp fishery operations in Kerala coast: Problems and Prospects. International Journal of Fisheries and Aquatic Studies, 1 (6). pp. 237-242. (http://eprints.cmfri.org.in).
4. **C.P. Rajool Shanis**, K.V. Akhilesh, U. Ganga & N.G.K. Pillai, 2012. New record of the rock shrimp *Sicyonia parajaponica* Crosnier, 2003 from Indian waters. *Indian J. Fish 60(1)* : *131-132, 2013*(http://eprints.cmfri.org.in).
5. **C.P Rajool Shanis** and Shyam, S Salim and Shridhar, Nivedita and Pillai, N G K (2014) Economic efficiency of deep sea shrimp fishery operations in Kerala. Journal of Fisheries Economics and Development, 15 (1). pp. 1-13. (http://eprints.cmfri.org.in).
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Shrimps of the family Pandalidae (Caridea) from Indian waters, with new distributional record of *Plesionika adensameri* (Balss, 1914)

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Original Article

Abstract

Twenty four species of Pandalid shrimps reported from the Indian waters, of which six genera *(Chlorotocella, Chlorotocus, Chlorocurtis, Dorodotes, Heterocarpoides* and *Stylopandalus)* are represented by single species each. The genera, *Plesionika* and *Heterocarpus* are represented by eleven and seven species respectively. *Plesionika adensameri* (Balss, 1914) a deep-sea shrimp hitherto unreported from Indian waters is recorded from west coast of India. Information on some biological aspects of few Pandalid shrimps from Indian waters is also reported in the present paper.

Keywords: *Pandalidae, Plesionika adensameri, Indian EEZ, Deep-sea shrimp.*

Introduction

Pandalid shrimps play an important role in the marine ecosystem as they constitute a major part of the diets of mesopelagic and deep-sea fishes. They also form a major share of the world shrimp market (Bergstrom, 2000). The Family Pandalidae (Caridea) is a diverse group with more than 189 species in 23 genera (De Grave *et al*., 2009). Pandalid shrimps are characterised by the presence of microscopically small or sometimes absent chelae on first pair of pereiopods and the subdivided carpus of the second pereiopod.

Though Pandalid shrimps are the most diverse group in deep-sea shrimp resources, very few studies on this group are available from Indian EEZ. Of the twenty four species of Pandalid shrimps reported from Indian EEZ, only four species have fishery importance and they are the largest contributor to deep-sea shrimp fishery of India (Nandakumar and Manissery 2006). The studies and records of many species of deep-sea shrimps from Indian waters dates back to early 20th century mainly from the surveys of the RIMS *Investigator* (Wood-Mason and Alcock, 1891; Alcock and Anderson, 1894,1899; Alcock, 1901; Kemp, 1925). Abundance and availability of deep-sea shrimp resources along the Indian coast have also been reported by John and Kurian (1959), Kurian (1965), George (1966), Silas (1969), Mohamed and Suseelan (1973), Thomas (1979), Oommen (1980), Suseelan *et al*. (1989), Ninan *et al*. (1992) and Kurup *et al*. (2008) based on exploratory surveys. Studies on diversity and biological aspects of deep-sea and pandalid shrimps from Indian waters are limited to the works of Suseelan and Mohamed (1968), Suseelan (1974), Lalitha (1980), Dineshbabu *et al*. (2001), Nandakumar *et al*. (2001), Thirumilu and Rajan (2003), Radhika (2004), Radhika and Kurup (2005) and Anrose (2009). Targeted deep-sea shrimp fishing started in the early 1990s in the Indian EEZ. Considering the tropical importance of sustainability in deep-sea fisheries, the present study collects information on

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Misidentification in fishery: the case of deep-sea pandalid shrimp *Plesionika spinipes* (Spence Bate, 1888) from Indian waters

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Abstract *Plesionika* (Spence Bate, 1888) is the most species diverse genus in the family Pandalidae and has wide geographic distribution all over the world. *Plesionika spinipes* Spence Bate, 1888 is one of the most important shrimps in the commercial deep-sea shrimp trawl fleet in the southern coast of India. The present study confirms that all previous records of *P. spinipes* in Indian fishery correspond to the closely similar species *P. quasigrandis* Chace, 1985. A table of morphological characters separating both species is provided.

Keywords Deep-sea shrimp; Misidentification; Pandalidae; *Plesionika*; India

Introduction

The genus *Plesionika* Spence Bate, 1888 has wide distribution all over the world and it is one of the most species rich genera in the family Pandalidae with 92 described species (De Grave and Fransen, 2011).The deep-sea habitat of *Plesionika* species makes their distribution more restricted than that of the pelagic shrimps, which contributes to speciation within the genus (Cardoso Irene, 2011). Eleven species of *Plesionika* are reported to occur in Indian waters (Rajool Shanis *et al.*, 2012), most of them are rare in the fishery, except *P. martia* (A. Milne-Edwards, 1883) and the so called *P. spinipes* Spence Bate, 1888. In the deep-sea shrimp fishery of India, *P. spinipes* is one of the most dominant species (Rajool Shanis *et al.*, 2012; Radhika , 2004; Rajan *et al*., 2001). The *Plesionika narval* (Fabricius, 1787) group consists of fourteen species including *P. spinipes* and the closely related *P. grandis* Doflein, 1902 and *P. quasigrandis* Chace, 1985 (Chan and Crosnier, 1991). The *P. narval* group is characterized by the rostrum being very long and armed with numerous closely set teeth along almost the entire length of both dorsal and ventral sides. The species in this group are very similar morphologically, often causing misidentification. Chan and Crosnier (1991) and Fransen (2006) doubted the validity of *Pandalus* (*Parapandalus*) *spinipes* reported by Alcock (1901) from Kanyakumari and the taxonomic description of the species provided by George and Vedavyasa Rao (1966) from the southwest coast of India and suggested that the species in Indian waters may be *P. grandis* or *P. quasigrandis*. This report provides morphological characters for the three species in question to discuss the identity of *P. spinipes* in Indian waters .

1 Materials and Methods

Samples of *Plesionika* spp. were collected from deep-sea shrimp trawler landings at Kollam and Cochin fisheries harbour (Kerala) , Southwest coast of India, Arabian Sea and Tuticorin fisheries harbour (Tamilnadu) , Southeast of India, Bay of Bengal (Figure 1). Measurements were taken using a digital caliper to the nearest 0.01 mm and the total length (TL) measured from the tip of rostrum to tip of telson and carapace length (CL) from the orbital margin to the posterior dorsal edge of the carapace. The identification and description of species in the present study are in accordance to Chan and Crosnier (1991) and Chace (1985).Specimens examined in the present study are deposited in the collection of National Bureau of Fish Genetic Resources, Cochin Unit, Cochin, India (NBFGR CH) and Pelagic Fisheries Division in Central Marine Fisheries Research Institute (CMFRI, PFD), Cochin, Kerala, India.

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Note

New distribution record of the rock shrimp, *Sicyonia parajaponica* Crosnier, 2003 from Indian waters

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ABSTRACT

The present study reports the first record of rock shrimp, *Sicyonia parajaponica* Crosnier, 2003 from Indian waters. The diagnosis of the new record was based on the examination of two male and one female specimens, collected from a commercial trawler operating in the Arabian Sea off the south-west coast of India during December 2010. Present report of *S. parajaponica* from the Arabian Sea fills the gap in its known distribution range from South China Sea to Gulf of Aden at 10 to 200 m depths.

Keywords: Arabian Sea, Sicyoniidae, *Sicyonia parajaponica*

Rock shrimps of the family Sicyoniidae Ortmann, 1898 are benthic penaeoids comprising of monotypic genus, *Sicyonia* H. Milne Edwards1830 with more than 52 species globally (Perez Farfante and Kensly, 1997; Crosnier, 2003). The rock shrimps are distributed predominantly in tropical and subtropical waters in the depths of few meters to nearly 1000 m deep. Sicyoniids can be easily distinguished from all other penaeoids by their thick, rigid and stony exoskeleton, shorter legs and absence of endopodite of the last three pairs of pleopods. Sicyoniid shrimps show diverse morphological variations and wide range in size among the species (Perez Farfante, 1985).

Sicyonia parajaponica was described by Crosnier (2003), collected from Philippines waters (Western Luzon) at depth range of 185-200 m. Crosnier (2003) divided the Indo-West Pacific Sicyoniid shrimps into eight groups and placed *S. parajaponica* under the "*lancifer*" group. Other members in the group are *S. lancifer, S. japonica, S. furcata* and *S. ocellata.*

The specimens of S. *parajaponica* (Fig. 1) described here were collected in December 2010 from a commercial trawler operated in the Arabian Sea, off the south-west coast of India. This is the first report of the species from Indian waters. The shrimps were deposited in the National Marine Biodiversity Museum at Central Marine Fisheries Research Institute (CMFRI), Cochin (Accession number: ED. 1.4.1.2)

Material examined

Three specimens, one female (TL 65 mm, CL 16.9 mm) and two males (TL 59-64 mm; CL 15.6-16.8 mm) collected from a commercial trawler, operated in the Arabian Sea which landed at Sakthikulangara Fisheries Harbour, Kollam, south-west coast of India, in December 2010, were used for the diagnostic studies for the species identification.

Diagnosis

Rostrum not overarching scaphocerite, with its tip bidentate. The dorsal carina of the carapace bears 5-8 teeth, with posterior 4 or 5, large and strong. One tooth is present on the ventral side of the rostrum. The hepatic spine is strong and well developed. Infraorbital lobe is rounded or slightly biangular. A blunt spine like out-growth is present behind the hepatic spine. The scaphocerite is triangular and with the disto-lateral tooth overreaching the lamella. The third maxillipeds are strong and reach beyond the tip of the scaphocerite. Process of distal ventrolateral lobes of petasma stretched transversely. Thelycum with rear part considerably enlarged. The dorsal tooth of first abdominal segment well developed, tip pointing upwards. The tooth of the second abdominal segment well developed, strong and acute. The anterior three abdominal segments are usually with single spine on the postero-ventral margin, whereas the fourth has three spines and fifth with two spines.

Fig. 1. *Sicyonia parajaponica* Crosnier 2003 from Arabian Sea, south-west coast of India

FS-C7

SHRIMP TRAWLING IN THE DEEP SEA-STATUS AND FUTURE CHALLENGES

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ABSTRACT

The current level of fish harvest exhibits serious threat to the fish food security in the country and poses the need to explore, identify and utilize nonconventional fisheries resources. Kerala is one of the coastal states of India where the deep sea shrimp trawling operations were carried out on a large scale since a decade back. Presently the annual deep-sea shrimp landings showed an overall decreasing trend. The present study analyzed the impediments in deep sea shrimp fishery operations and revealed that the high operational cost, high risk and efforts, lack of skilled and trained manpower, low market price realisation, abundance of discards, poor quality of shrimps, low level of harvesting technology perceived a major hurdles in deep sea shrimp fishery sector. The study suggests the need for improved governmental support in deep sea operations for the sustenance of the sector in ensuring fish food security for the Kerala populace.

Key words: *Deep Sea, shrimp fishery, Status, Issues, Kerala*

INTRODUCTION

Fishery sector continues to be one of the fastest growing food sectors in the country in addition to the aquaculture. The current level of marine fish production in India is around 3.78 million tonnes [1]. Marine fisheries constitute an important sector in the nation not only as a major food source but also as a generator of export earnings and employment. Globally, the trend shows that the consumption of fish is on a rise and there has been an unceasing increase of issues pertaining to food security in terms of spiralling of the fish prices as well as non-availability of fish. With the decrease in catch per unit effort of fish resources there is a critical requisite to identify new fishery resources to sustain the fish food security of the country.

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A new species of the genus *Parastylodactylus* Figueira, 1971 (Crustacea: Decapoda: Caridea: Stylodactylidae) from off Kollam, southwest coast of India

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Abstract

A new species of the caridean genus *Parastylodactylus* Figueira, 1971 (Stylodactylidae), *P. sulcatus*, is described and illustrated on the basis of three male specimens from the Southern Arabian Sea, off the southwest coast of India, at a depth of 350 m. Morphologically, the new species appears closest to *P. bimaxillaris* (Bate, 1888) widely distributed in the Indo-West Pacific, but the much longer rostrum, the absence of a supraorbital tooth on the carapace, the deep hepatic groove on the carapace and the relatively longer and more slender third pereopod distinguish the new species from *P. bimaxillaris*. It is the first representative of the genus from Indian waters. An updated key to the species of *Parastylodactylus* is presented.

Key words: Crustacea, Decapoda, Caridea, Stylodactylidae, *Parastylodactylus*, new species, Arabian Sea, India

Introduction

The stylodactylid shrimp genus *Parastylodactylus* was established by Figueira (1971) to accommodate *Stylodactylus bimaxillaris* Bate, 1888. The genus is characterized by the absence of a palp on the mandible and the presence of arthrobranchs above the bases of the first to fourth pereopods in both males and females. The following seven species, all recorded from the sublittoral to the upper bathyal zone in the Indo-West Pacific region, are currently included in the genus: *P. bimaxillaris* (Bate, 1888), *P. hayashii* (Komai, 1997), *P. longidactylus* Cleva, 1990, *P. moluccensis* Cleva, 1997, *P. richeri* Cleva, 1990, *P. semblatae* Cleva, 1990, and *P. tranterae* Cleva, 1990 (Cleva 1990, 1997; Komai 2011). In addition, Hayashi (2007) indicated the existence of one undescribed species, previously referred to *P. semblatae* (cf. Hayashi 1991), from Japanese waters.

Three specimens of a stylodactylid shrimp were obtained by the second author from the by-catch of a deep-water shrimp trawler, operated off Kollam, southwest coast of India. On close examination, it was revealed that these specimens represent an undescribed species of *Parastylodactylus*, appearing closest to *P. bimaxillaris*. In this contribution, we thus describe a new species, *P. sulcatus*, on the basis of these three specimens.

The holotype and one paratype are deposited in the Natural History Museum and Institute, Chiba, Japan (CBM). One paratype is deposited in the Marine Biodiversity Referral Museum at the Central Marine Fisheries Research Institute (CMFRI), Cochin, India. Postorbital carapace length (cl) is used as the standard measurement indicating the size of the specimens. For comparison, the following material was examined.

Parastylodactylus bimaxillaris: 1 male (cl 5.1 mm), 1 female (cl 4.7 mm), off Tong Kong, southwestern Taiwan, depth unknown, 5 August 1996, commercial trawler, coll. T. Komai, CBM-ZC 2863; 4 ovigerous females (cl 5.3–6.6 mm), Dashi Fishing ground, off northeastern Taiwan, 300–400 m, 4 December 1997, commercial trawler, CBM-ZC 3878.

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Deep-sea shrimp fishery operations in Kerala coast: Problems and Prospects

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Abstract
Deep-sea shrimp fishery operations in Kerala were initiated since 1999 with high landings which subsequently dropped considerably. The present study assesses the different problems faced by trawl-operators in deep-sea shrimp fishing operations. High operational cost, high risk and efforts, lack of skilled and trained manpower, low market price realisation, abundance of discards, poor quality of shrimps, low level of harvesting technology perceived a major hurdles in deep-sea shrimp fishery sector. The study suggests the need for improved governmental support in deep-sea operations for the sustenance of the sector in ensuring fish food security for the Kerala populace.

Keywords: Deep- Sea, shrimp fishery, economic efficiency, Issues, bycatch.

1. Introduction
Fish and fish products is one of the world's most widely traded foods and play a pivotal role in the global food economy. They constitute an important sector in many maritime nations not only as a major food source but also as a generator of forex earnings and employment. Fish contributes 17 percent of the global population's intake of animal protein and provides essential minerals, vitamins and omega -3 fatty acids [1]. Fisheries sector play as a source of employment for more than 200 million people in worldwide [2]. In comparison to other sectors of the world food economy, however, the fisheries and aquaculture sectors are poorly planned, inadequately funded, and neglected by all levels of government [3].
Fishery sector continues to be one of the fastest growing food sectors in the country in addition to the aquaculture. The current level of fish marine production in India is around 3.94 million tones [4]. Kerala contributes a large share to national marine fish production and generates around 8 lakhs tone of fish annually with sizeable contribution by pelagic fishes (73 percent) and demersal fishes (16 percent), crustaceans (6 percent) and molluscan (5 percent) resources. The per capita fish consumption in Kerala found to be 27 kg/ year and it crosses the national average [5].
Even though their normal little size, shrimps collectively represent the biggest and most valuable seafood commodity traded worldwide. Over the last two decades worldwide production of shrimp has increased exponentially and accounts for 16 percent of global seafood exports [1]. The shrimps occupy a prominent position in the economy of India on account of its high export value among the marine fishery resources of the nation. During the year 2012-13 the shrimp export generated the value of 8833.29 crores from an export quantum of 2.09 lakh tonnes [6]. In addition domestic shrimp consumption is on the rise with increased consumer willingness to pay for shrimp across the different consumption centers [7].
The marine fishing sector has witnessed vast technological developments in both harvest and post-harvest area during the last few decades. Globally capture fisheries faced by many issues and poor economic returns is one of the major problem. Economic research in the field of fisheries assumes a main part for forecasting appropriate policy measures and planning the future development schemes. In India all types of fishing units on an average run on profit as their earnings exceed, the break-even point mainly due to favourable price trend and even if due to nature of competition of open access marine fisheries, some of the less efficient units

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An account on the deepsea shrimp *Aristaeopsis edwardsiana* (Johnson, 1867) from the Indian EEZ

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ABSTRACT

Aristaeopsis edwardsiana (Johnson,1867) is a deepsea shrimp of the continental slope that has not yet been reported in the targeted deepsea crustacean fishery along the Indian coast. An exploratory survey on-board FORV *Sagar Sampada* in the Arabian sea at a depth of 950 m off Trivandrum (lat. 8 ^{0} 28' N and long. 76 ^{0}14' E) yielded a catch of *A. edwardsiana* at a high catch per unit effort (CPUE) of 14 kg h^{-1}. The biological aspects of this less known deepsea shrimp species such as length frequency distribution, morphometric relations, sex ratio and the additional sexual dimorphism manifested in the antennal scale of males are reported.

Keywords: *Aristaeopsis edwardsiana*, Aristeidae, Deepsea shrimp, Indian EEZ

Introduction

The aristeid shrimp *Aristaeopsis edwardsiana* (Johnson, 1867) popularly known as the scarlet shrimp (formerly *Plesiopenaeus edwardsianus*) was reported in the Indian EEZ by Alcock (1910) and its occurrence off Trivandrum (lat. 8 ^{0} 28' N and long. 76 ^{0}14' E) at depths > 800 m, based on four specimens caught was confirmed by Suseelan and George (1990). In the present study, during an exploratory survey in the same region (lat. 8 ^{0}24' N and long. 76 ^{0} 07' E) the CPUE of *A. edwardsiana* was 14 kg h^{-1} which was quite high in comparison to reports of catch rates of 2 kg h^{-1} off the Portugal continental slope (Figueiredo *et al*., 2001) and 3.7 – 10 kg h^{-1} reported off Brazilian coast where a sustainable targeted deep-sea fishing for aristaeid shrimps is prevalent (Pezzuto *et al*., 2006).

A. edwardsiana is characterised by features like the absence of exopods on the first to fifth pereopods, first and second pereopod without distal meral spine and the absence of hepatic spine (Farfante and Kensley, 1997). Molecular phylogenetic analysis has established that *Aristaeopsis* is distinct from the *Plesiopenaeus* but closely related to *Aristaeomorpha*, another important genus in the family aristeidae (Ma *et al*., 2009). Considering the fact that deepsea shrimps in general have biological traits such as slow growth, late maturity and low fecundity making them especially vulnerable to over-exploitation as compared to coastal shrimp species (Nandakumar *et al*., 2001), detailed studies on the biology of the species are necessary before its exploitation by commercial vessels are allowed. The present study therefore explores a sample of *A. edwardsiana* caught during the exploratory deep-water fish survey for biological details.

Materials and methods

Samples were collected during an exploratory deepwater research survey (FORV *Sagar Sampada* cruise No.281) using High Speed Demersal Trawl - Crustacean Version (HSDT CV) net at a depth of 950 m. The species appeared in a catch mix consisting of finfish, crustacean and chondrichthyans and was identified based on distinguishing characters as given by Farfante and Kensley (1997) and Poore and Ahyong (2004). Standard morphometric measurements of the sample included total length (TL) as measured (in mm) from tip of rostrum to tip of telson; and carapace length (CL) from posterior margin of the orbit to posterior dorsal margin of carapace (Dall *et al*., 1990). The specimens (n = 224) were differentiated among sexes using the characters of presence of petasma (males) or thelycum (females) and the relationship between TL and CL was derived using the linear relationship, Y= a + bX for males and females separately. Besides this, sexual dimorphism manifested as appearance of antennal scales in males in certain aristeid shrimps is described for this species in Indian waters for the first time.

Results

Length Frequency distribution and sex ratio

The total length (TL) varied from 168 to 295 mm and carapace length (CL) from 51 - 95 mm. The minimum and

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First record of the reef lobster *Enoplometopus macrodontus* Chan and Ng, 2008 from Indian waters

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Abstract

The reef lobster *Enoplometopus macrodontus* was caught during the deep sea trawl operations off Chavakkad from a depth of 320 m. About ten specimens were landed at the Kalamukku Fishing Harbour, Kochi. The carapace length was 66-75 mm and weight was 79.3-94.2 g. This is the first report of the species in the Indian waters. The species has a smooth carapace with hair on the abdomen, chelipeds and telson. The morphological characters along with colour pattern are described.

Keywords: reef lobster, Enoplometopidae, Indian waters

Introduction

Enoplometopus macrodontus, also referred to as reef lobster, is a member of the family Enoplometopidae under the order Decapoda. Holthuis (1983) considered *Enoplometopus* as Axiids (Infra order: *Thalassinidea,* now *Axiidea* see De Grave *et al*., 2009) rather than Nephropsids. They can be distinguished from the clawed lobsters of the family Nephropidae by the presence of full claws on the first pair of the pereiopods, the second and third pairs being only sub-chelate. They have a shallow cervical groove compared to the clawed lobsters in which the cervical groove is deep. *E. macrodontus* is relatively a newly recorded species which was first reported from Balicasay Island, near Panglao, Visayas Central Philippines in 2002 probably from depths of 90-200 m (Chan and Ng, 2008). Totally twelve species have been recorded under this genus, two from the Atlantic, four from the Indo-West Pacific region, two from West Pacific, two from Philippines, one from Reunion and one species from French Polynesia, New Caledonia and Japan (Chan and Ng, 2008). They are brightly coloured inhabiting rocky reefs or in the deeper part of the reef slopes and are nocturnal and timid. This is the first record of the species from the Indian coast.

Material and Methods

Ten specimens were observed in the deep sea trawl landings at the Kalamukku (Kochi) Fishing Harbour on 17/9/2009. The specimen measured 66-75 mm in carapace length, 143-170 mm in total length and weighed 79.31-94.2 g. They were caught off Chavakkad (10° 30', 75° 24') from a depth of 320 m. The specimens were identified following the keys provided by Chan, (1998) and Poupin (2003). A specimen is deposited in the Marine Biodiversity Referral Museum of the Central Marine Fisheries Research Institute, Kochi, India (Acc.No. ED. 3.4.1.1, date 14.10.2009). The Crusher Propodite Volume index for four male specimens was estimated by the method of Aiken and Waddy (1980) by using the equation

$$CPV = \frac{LxWxD}{CL} \times 10$$

The chelipeds in male lobsters increase in volume on attaining maturity. This index known as 'Anderson-Cheliped Index' when plotted against the carapace length for a range of males, produces an inflection which corresponds to the size at maturity for the species of that area.

Results

***Material examined*:** 10°30', 75°24', off Chavakkad, Kerala, South West coast of India.

Class: Malacostraca; Order: Decapoda; Suborder: Pleocyemata Burkenroad, 1963; Infraorder**:** Astacidea, Latreille, 1802; Family: Enoplometopidae